volcano, Heceta Bank is a basaltic outcrop, and Coquille Bank is an outcrop of exfoliating siltstone and mudstone. At this gross scale, comparing the banks is like comparing apples and oranges.

The ranges of depths sampled at the three banks were similar (Table IV-1). The correlation between depth and bottom type we found at Heceta Bank from 1988 to 1990 (Chapter 3), was evident on the other two banks. That is, on average, rock ridges were found at the shallowest parts of all banks (except Coquille, which lacked this bottom type), boulder-cobble bottoms at moderate depths, and mud at the deepest depths (Fig. IV-1). This pattern is simply due to the fact that each bank is a rock outcrop extending upward from a mud bottom. Because depth and dominant substratum were correlated, we used only bottom type to characterize habitat in our analyses.

The gross-scale differences among banks are reflected, but somewhat obscured, when comparing bottom types among banks. Figure IV-2 shows the overall percent cover of the ten most prevalent bottom types sampled, which accounted for about 90% of the bottom covered by all transects combined. Clearly, Daisy Bank was dominated by boulder-covered bottoms, Heceta Bank by rock ridges and mud, and Coquille Bank by boulders, cobble, and mud.

Surprisingly, when we statistically examined the percent cover of all 30 bottom types we encountered, Daisy Bank was not significantly different from Coquille Bank, due largely to their shared high cover of boulder-cobble (codes BC and CB in Fig. IV-2, Kolmogorov-Smirnov two-sample tests, P>0.05). Daisy Bank was also not significantly different from Heceta Bank, due largely to

Figure IV-1. Depths (mean ± 1 SE) of patches of the dominant substrata sampled on Daisy, Heceta, and Coquille Banks in 1990. "Ridge" includes habitat patches with the bottom type code "RR". "Boulder-Cobble" includes all patches with a primary code of "B" or "C". "Mud" includes all patches with a primary bottom type code of "M". (See Chapter 2 for description of bottom type codes.) Sample sizes (number of patches per substratum by bank) are:

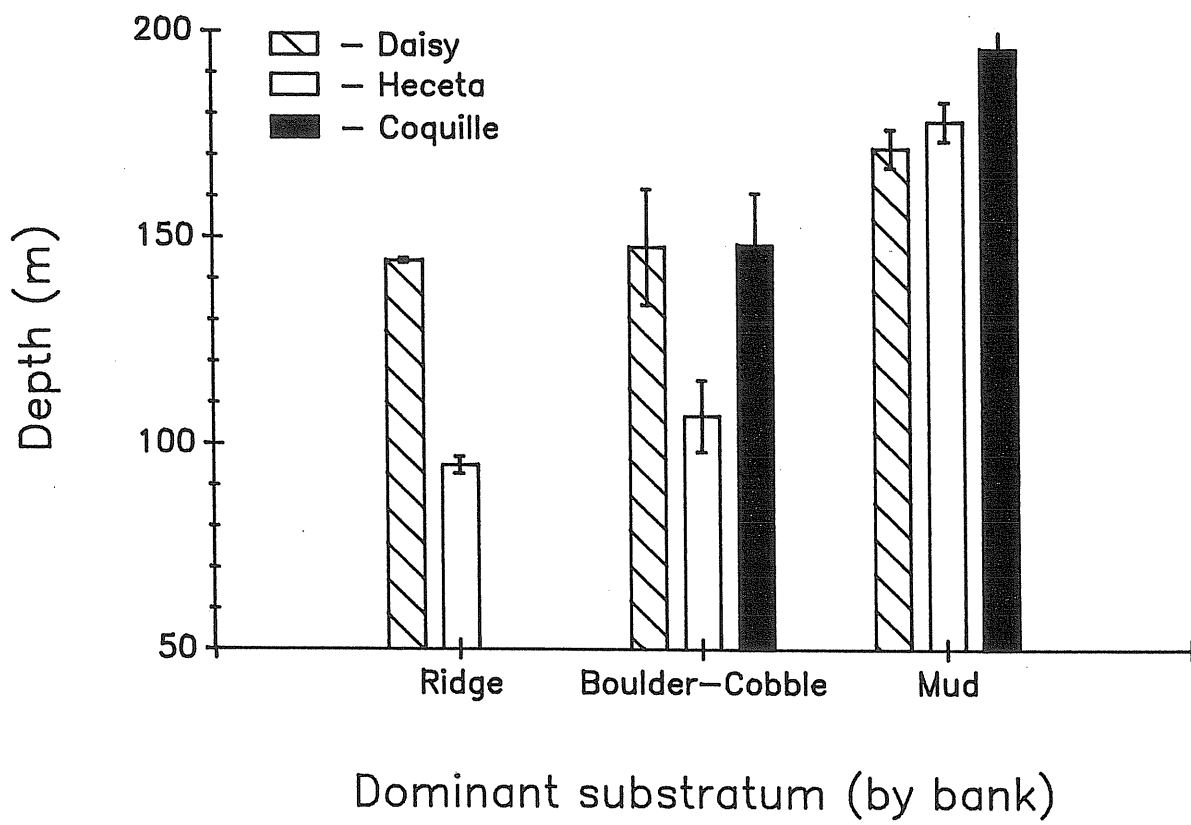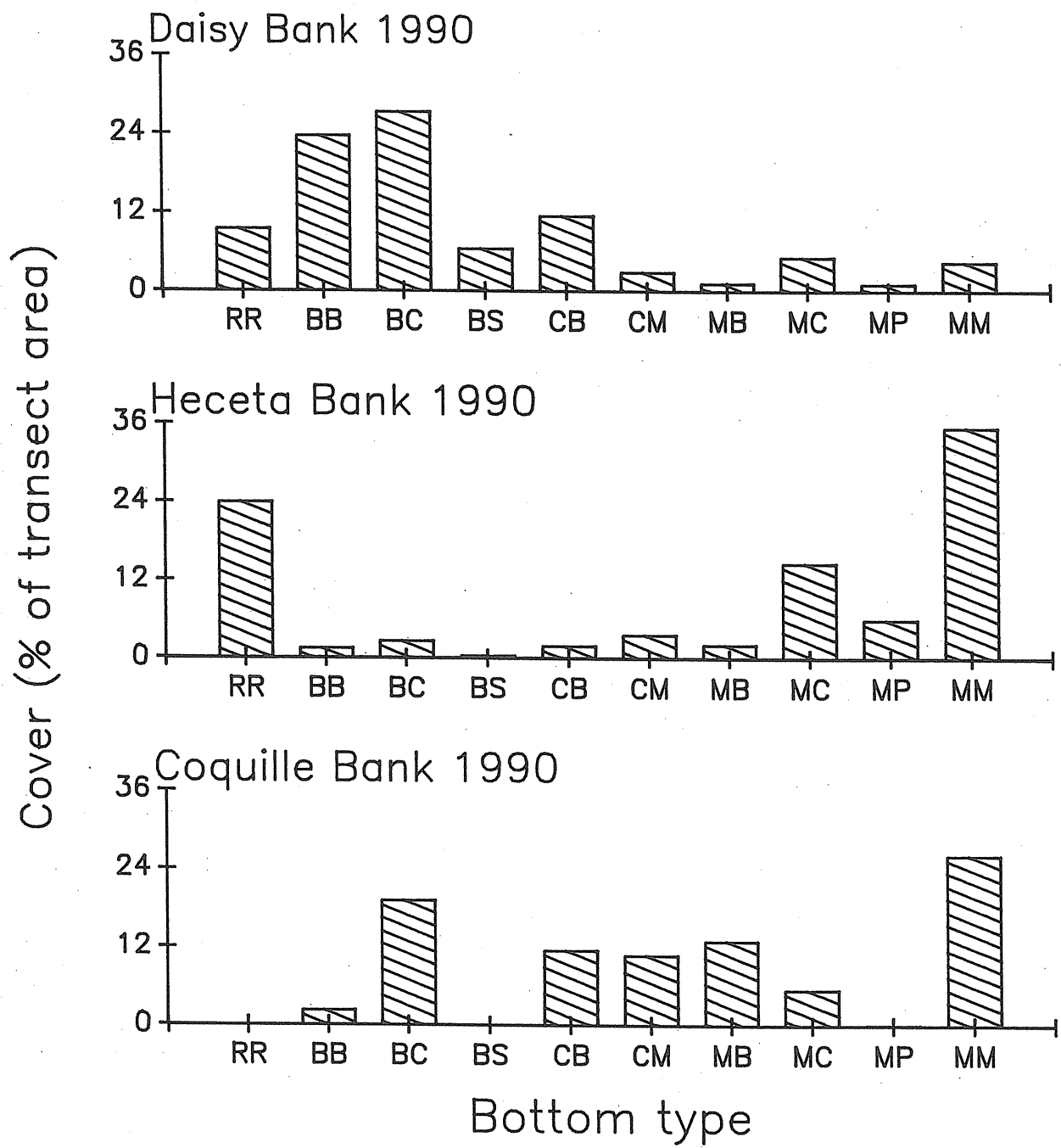| Substratum	Daisy	Heceta	Coquille
Ridge	26	145	0
Boulder-Cobble	109	152	138
Mud	18	236	58

(total number of patches = 882)

Figure IV-2.   Percent cover (mean ± 1 SE) of the ten

   dominant bottom types observed on Daisy, Heceta, and

   Coquille Banks in 1990.   Bottom types are listed by

   decreasing relief and particle size, where the first

   letter is the dominant substratum and the second letter

   is the second most prevalent substratum: R=rock ridge;

   B=boulder;   C=cobble;   P=pebble;   S=sand;   M=mud.   Sample

   sizes (number of patches by bank) are:

Bottom

type	Daisy	Heceta	Coquille
RR	26	145	0
BB	40	16	5
BC	29	34	40
BS	3	7	0
CB	26	17	36
CM	6	19	27
MB	3	17	24
MC	11	79	13
MP	2	42	1
MM	2	98	20

(total number of patches = 915)

Daisy Bank 1990

Heceta Bank 1990

Coquille Bank 1990

Cover (% of transect area)

Bottom type

their shared moderate cover of rock ridge (RR). (Note, however, that the nonparametric test we had to use is not particularly powerful for detecting true differences.) Clearly significantly different were Heceta and Coquille Banks (P=0.001).

The coarse level of resolution of these analyses of bottom type could easily obscure meaningful differences between the habitats and fish assemblages at the three banks. Even at the finer scale of sampling stations, meaningful between-bank comparisons would be obscured by the fact that each station represented a unique combination of bottom types. Therefore, comparisons of stations between banks would confound habitat and bank differences. This problem was circumvented by canonical correlation analysis (CCA), which compared habitats and fishes among the banks at the ecologically relevant scale of habitat patches, which are transect segments of uniform bottom type (see Chapter 2).

The first three axes of the CCA provided meaningful contrasts. Bottom-type loadings on these axes defined three basic habitat types among all three banks (Fig. IV-3). The first axis provided high positive loadings on boulder and cobble bottoms, the second provided high loadings on mud bottoms, and the third provided high loadings on rock ridges interspersed with pebbles. There were no strongly negative loadings on any axis.
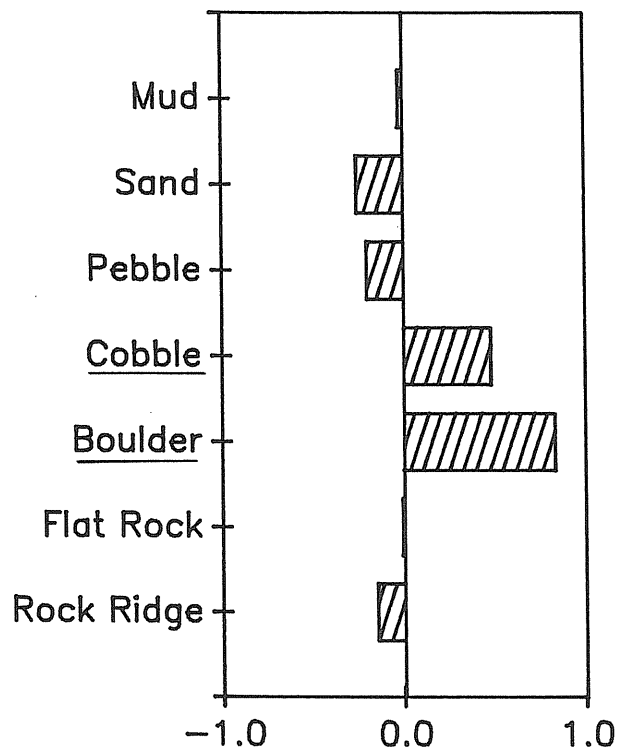
The canonical variate scores showed how each bank loaded on each of these three basic habitat types (bottom-type scores in Fig. IV-4):
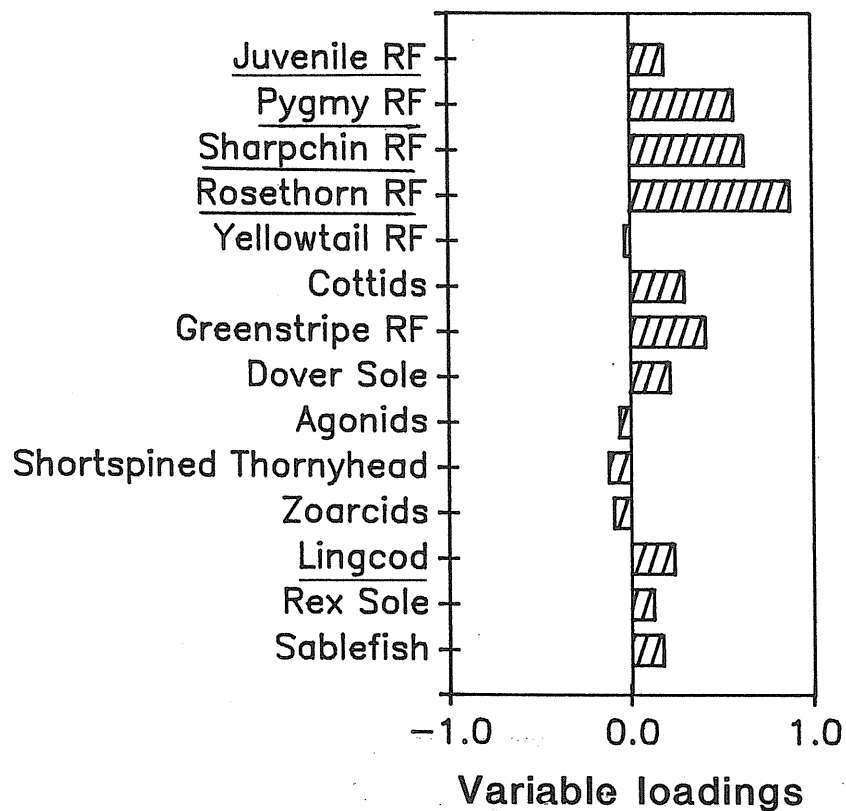
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Figure IV-3. Variable loadings of bottom types and fishes

on the three axes of the canonical correlation analysis.

The canonical correlation coefficient (r) measures the

overall association between bottom-type cover and fish

abundance. High positive loadings on axis 1 define a

boulder-cobble habitat with associated fishes

(underlined). High positive loadings on axis 2 define a

mud habitat with associated fishes (underlined). High

positive loadings on axis 3 define a ridge-pebble habitat

with associated fishes (underlined). Data for analysis

were derived from discrete habitat patches for which all

variables could be measured (n = 915, see table in

caption to Fig. IV-2).
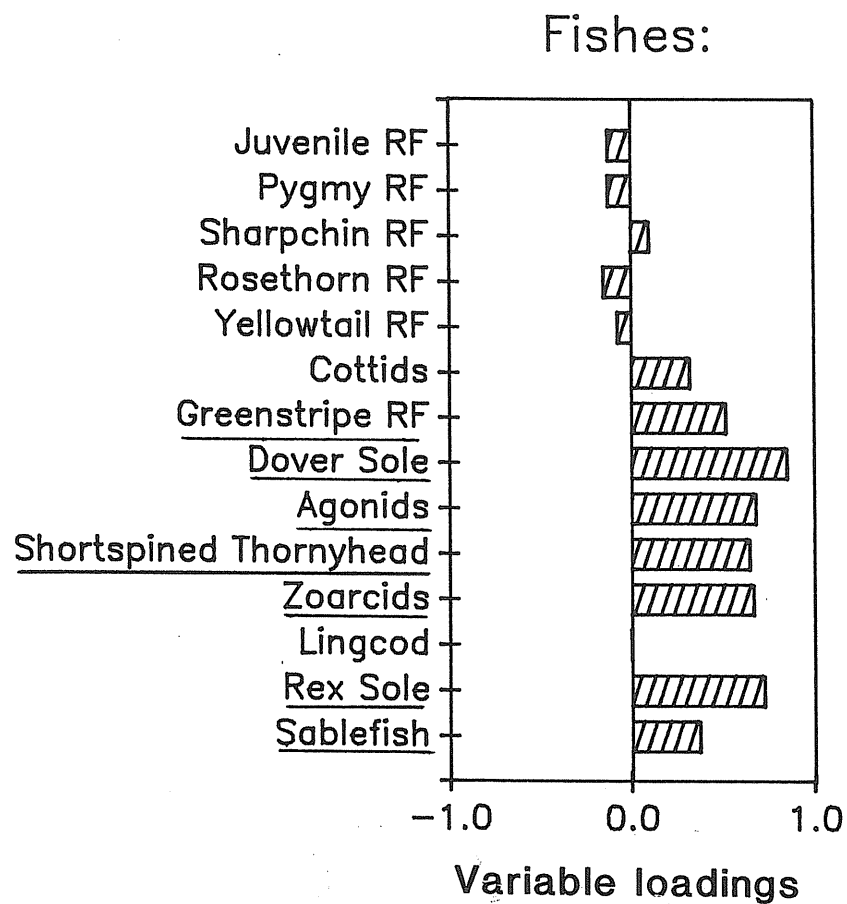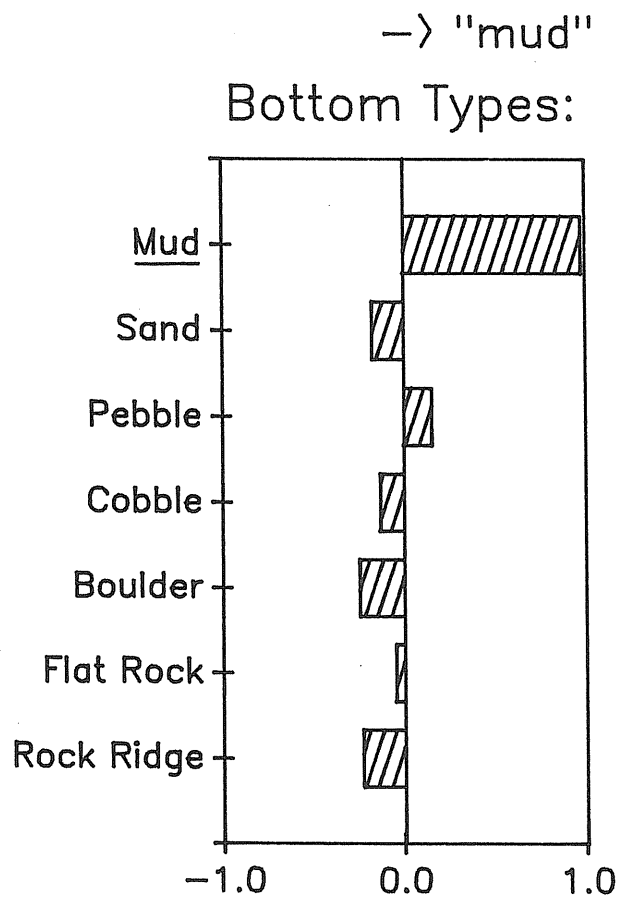
CCA Axis 1:
r = 0.74

Bottom Types:

Bar chart with values from -1.0 to 1.0:
- Mud
- Sand
- Pebble
- Cobble (underlined)
- Boulder (underlined)
- Flat Rock
- Rock Ridge

Fishes:

Bar chart with values from -1.0 to 1.0:
- Juvenile RF (underlined)
- Pygmy RF
- Sharpchin RF (underlined)
- Rosethorn RF (underlined)
- Yellowtail RF
- Cottids
- Greenstripe RF
- Dover Sole
- Agonids
- Shortspined Thornyhead
- Zoarcids
- Lingcod (underlined)
- Rex Sole
- Sablefish

Variable loadings

CCA Axis 2:
r = 0.63

Bottom Types:

Mud, Sand, Pebble, Cobble, Boulder, Flat Rock, Rock Ridge

-1.0   0.0   1.0

Fishes:

Juvenile RF, Pygmy RF, Sharpchin RF, Rosethorn RF, Yellowtail RF, Cottids, Greenstripe RF, Dover Sole, Agonids, Shortspined Thornyhead, Zoarcids, Lingcod, Rex Sole, Sablefish

-1.0   0.0   1.0

Variable loadings

$\rightarrow$ "ridge/pebble"

Bottom Types:

CCA Axis 3:
r = 0.33

Mud

Sand

<u>Pebble</u>

Cobble

Boulder

Flat Rock

<u>Rock Ridge</u>

-1.0   0.0   1.0

Fishes:

Juvenile RF

Pygmy RF

Sharpchin RF

Rosethorn RF

<u>Yellowtail RF</u>

<u>Cottids</u>

Greenstripe RF

Dover Sole

Agonids

Shortspined Thornyhead

Zoarcids

Lingcod

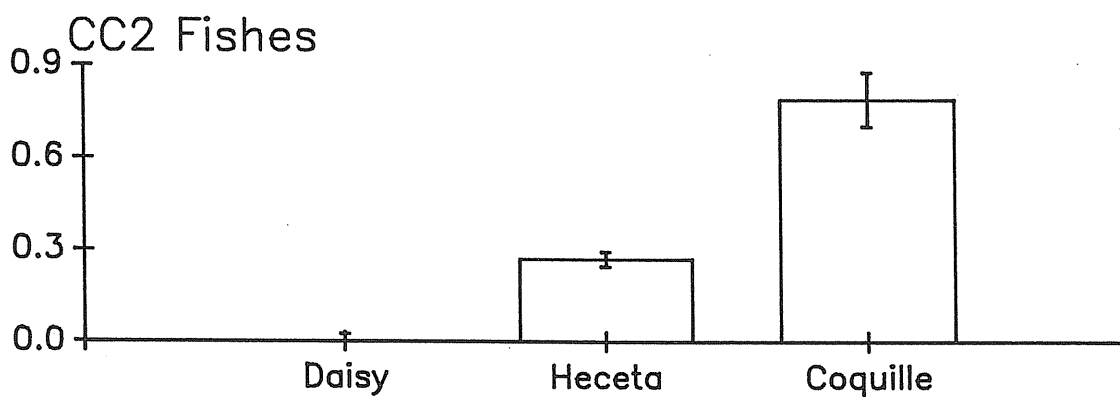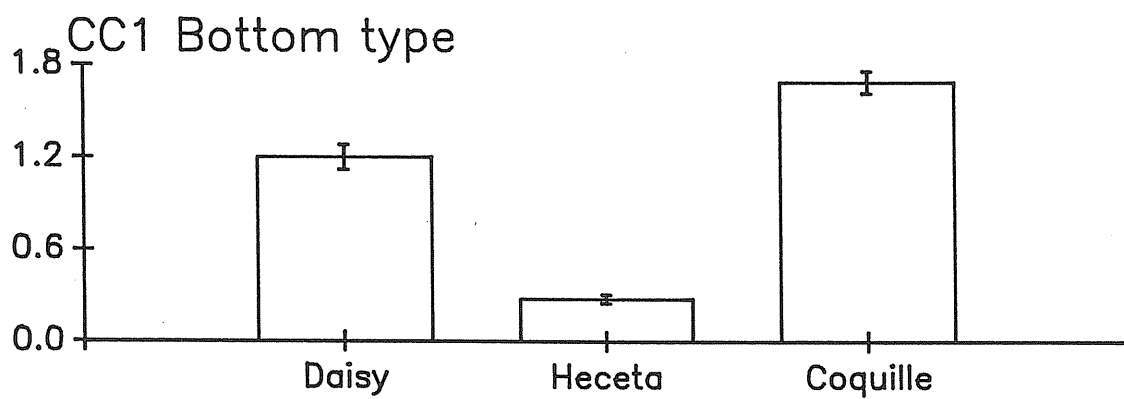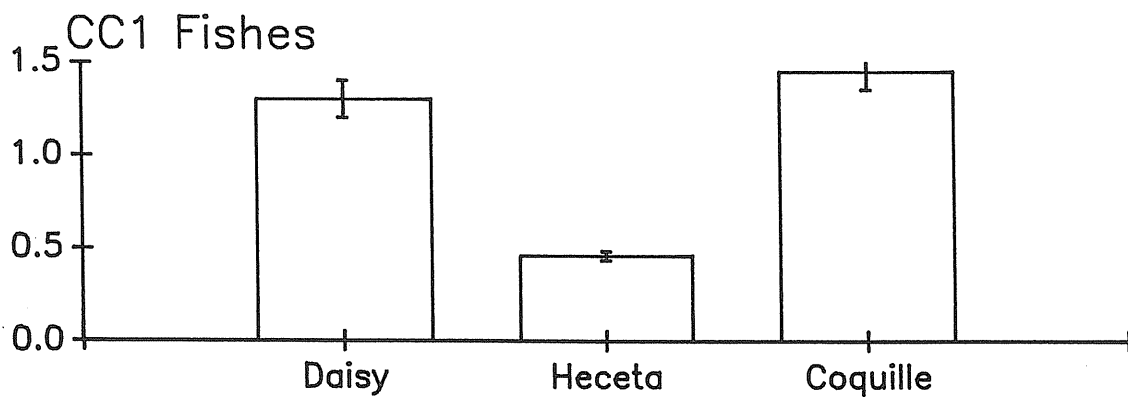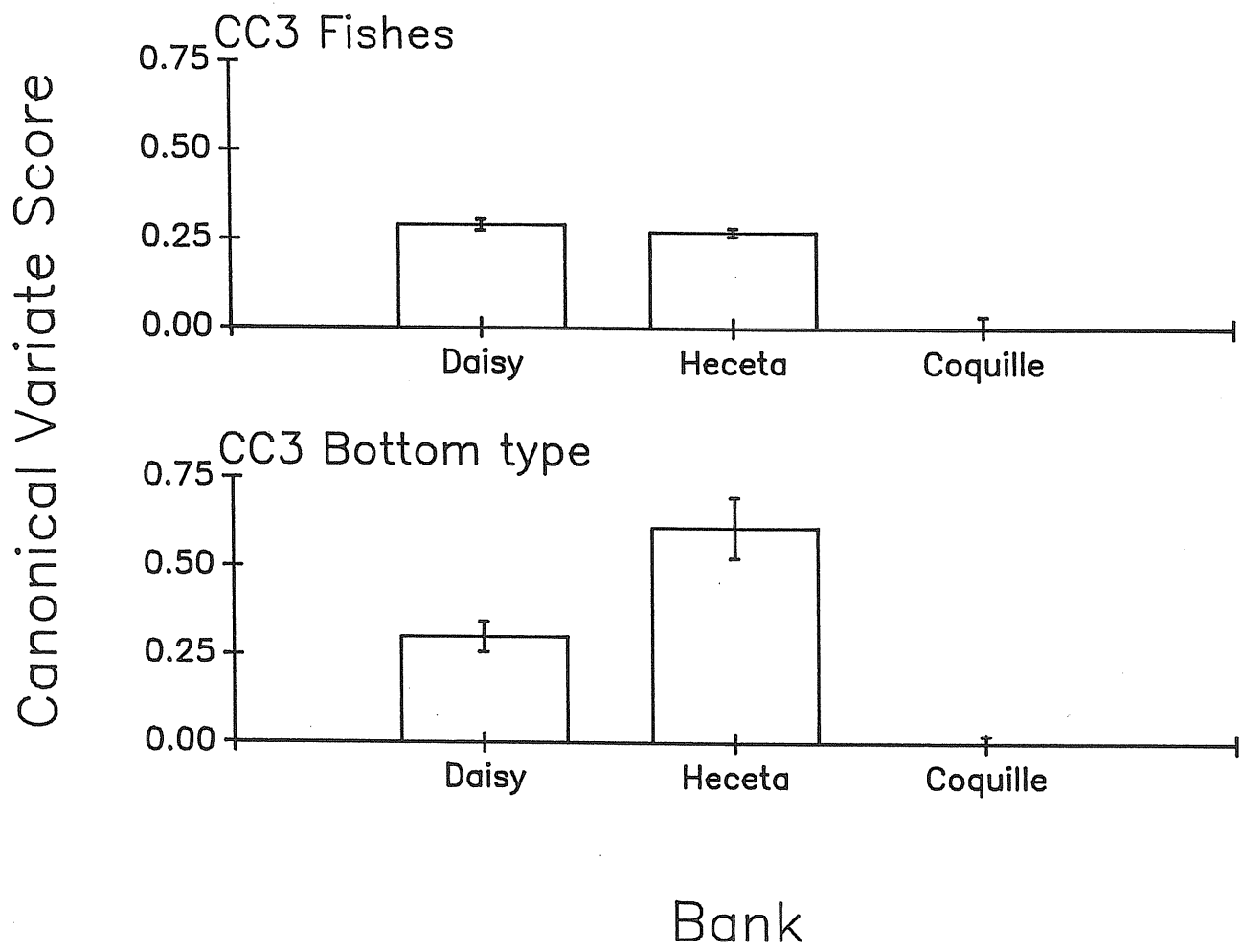Rex Sole

Sablefish

-1.0   0.0   1.0
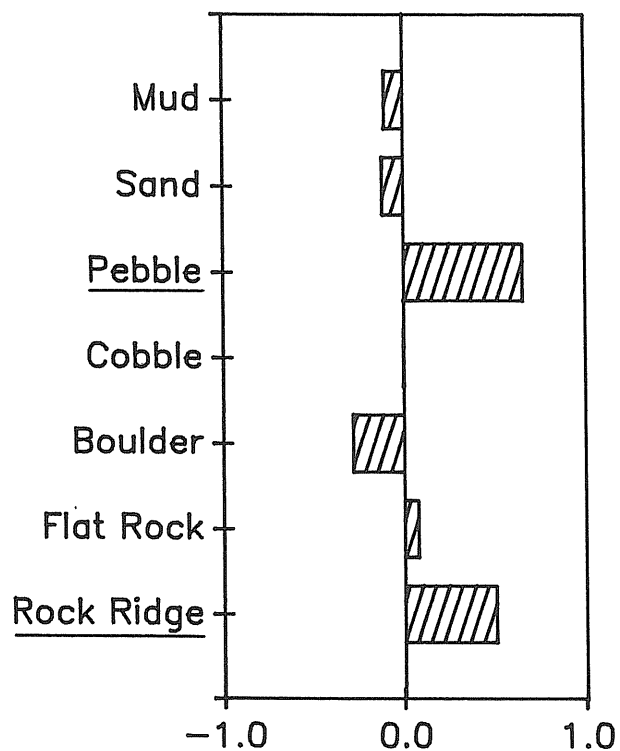
Variable loadings
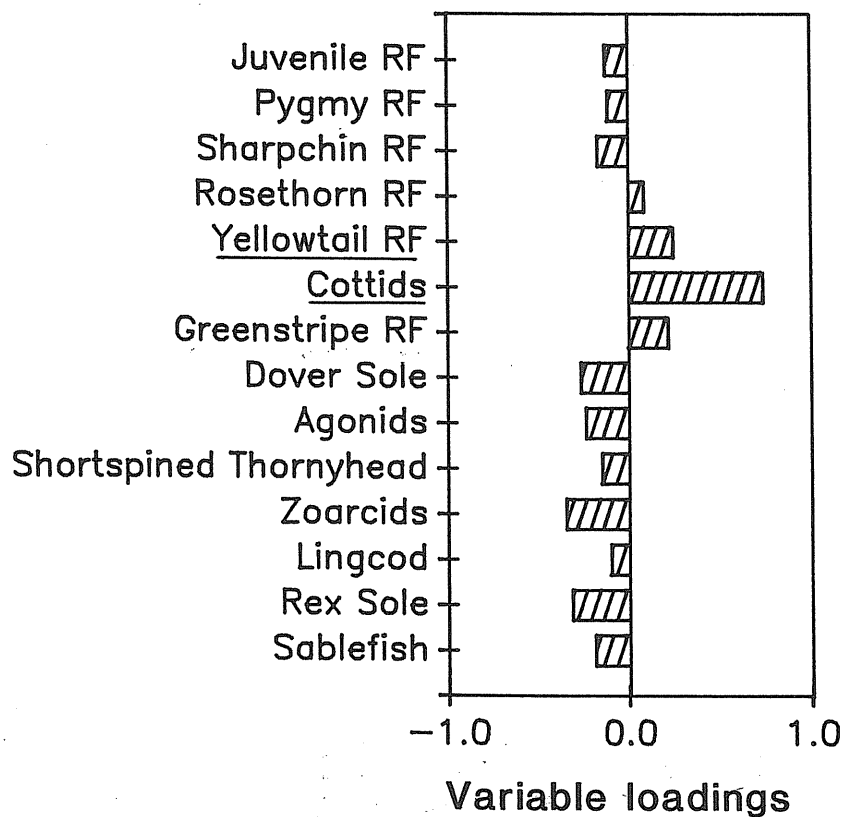
Figure IV-4. CCA variate scores for fishes and bottom types
(mean ± 1 SE) at Daisy, Heceta, and Coquille Banks in
1990. Banks with high scores on axis 1 (CC1) are
associated with with boulder-cobble habitats. Banks with
high scores on axis 2 (CC2) are associated with mud
habitats. Banks with high scores on axis 3 (CC3) are
associated with ridge-pebble habitats. Sample sizes
(number of patches) are: Daisy Bank, n = 167; Heceta
Bank, n = 576; Coquille Bank, n = 172 (total number of
patches = 915).

CC1 Fishes

CC1 Bottom type

CC2 Fishes

CC2 Bottom type

Canonical variate score

Bank

113

CC3 Fishes

CC3 Bottom type

Canonical Variate Score

Bank

114
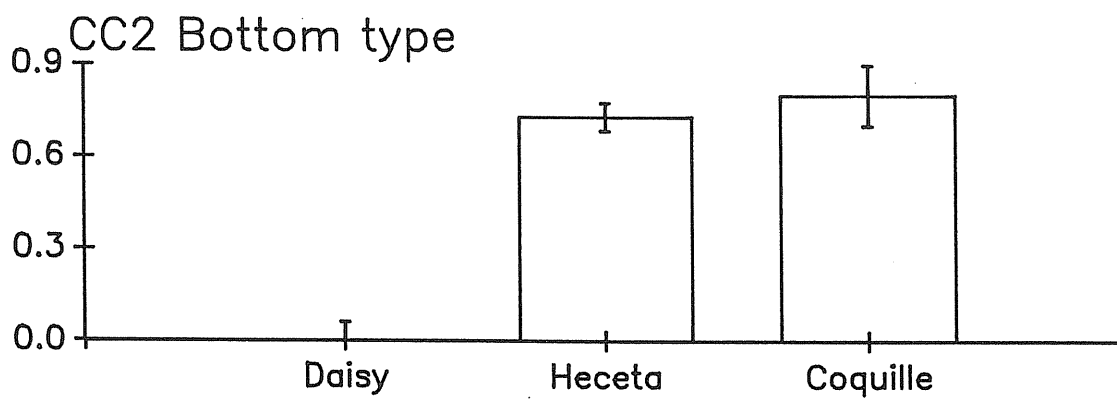
(1) <u>Boulder-Cobble Habitat</u>: Both Daisy and Coquille Banks scored highly on this first CCA axis, a reflection of both banks being largely covered by boulders and cobble at shallow and moderate depths (see codes BB, BC, BS, CB, and CM in Fig. IV-2). Note, however, that the boulders at Daisy Bank were mostly rounded, igneous structures, whereas those at Coquille Bank were mostly flatted, sedimentary structures, usually covered by a layer of silt (see Chapter 2: Fig. II-3). Heceta Bank scored about a third as highly as the other banks on this axis, meaning that Heceta is less dominated by boulders than are the other banks.

Chapter 3 characterizes the invertebrate assemblages over boulder-cobble bottoms at Heceta Bank. In general, Daisy and Coquille Banks supported invertebrate assemblages superficially similar to Heceta Bank (Appendices 1 and 3), but with some striking differences. Daisy Bank was the only bank where we observed the brachiopod *Crania*, and sponges in general were more prevalent and much larger there than the other two banks (some a meter tall). Coquille Bank supported a unique set of species associated with silt-covered boulders, including fours species of sponges, several species of gastropods and crustaceans, and a unique brittlestar (*Asteronyx*) and sea cucumber (*Psolus*, Appendices 1 and 3)

(2) <u>Mud Habitat</u>: Both Heceta and Coquille Banks scored highly on this second CCA axis because the deepest areas we sampled at both banks were dominated by mud (see codes MM, MP, MC, and MB in Fig. IV-2). Having a steeper profile and being surrounded by deeper water, we sampled relatively little mud at Daisy Bank.

The invertebrate assemblages on mud at Heceta Bank, described in Chapter 3, were generally similar to those at the other two banks, with some striking exceptions in terms of presence/absence (Appendices 1 and 3). We observed the sea pen *Balticinia* only at Coquille Bank, where it occurred in dense beds. Heart urchins (*Brissaster*) were encountered only at Heceta Bank. Finally, we observed no urchins or sea cucumbers at Daisy Bank, probably because we sampled little mud there.

(3) <u>Rock-Ridge Habitat</u>: Heceta Bank scored highest on this third CCA axis, about twice the score of Daisy Bank. This pattern reflected the fact that the shallowest parts of Heceta Bank are dominated by ridges, whereas less of the shallowest part of Daisy Bank we sampled comprised this habitat (see code RR in Fig. IV-2). We encountered no ridge habitat at Coquille Bank.

The dominant invertebrates on ridges at Heceta Bank, vase sponges and basketstars (Chapter 3), were absent from ridges on Daisy Bank (Appendices 1 and 3). Also unique to the ridges on Heceta Bank were the only algae we observed (*Codium* and crustose corallines), as well as the only hydrocorals (*Allopora*).

Fortunately, each of these three general habitats were common on two of the three banks, and always on different pairs of banks: boulder-cobble at Daisy and Coquille; mud at Coquille and Heceta; and rock ridge at Heceta and Daily. This pattern provided an ecologically meaningful opportunity for all possible pairwise comparisons between banks.

For statistical analysis, we considered 14 abundant and/or commercially valuable fish taxa chosen by three criteria (Table IV-2): (1) all rockfishes (including shortspine thornyhead) with more than 100 individuals observed among all banks (7 species); (2) all other identifiable taxa with more than 300 individuals observed among all banks (6 taxa); and (3) the largest predatory sportfish we observed, lingcod. These taxa accounted for over 96% of all fish we observed in 1990. We had to pool species in four of these taxa (juvenile rockfishes, cottids, agonids, and zoarcids) because, first, these fish were usually too small to identify to species from the submersible, videotapes, or photographs, and second, the submersible provided no means of capturing fish.

The three major habitats defined in the canonical correlation analysis (see above) were correlated with distinct fish assemblages among the three banks (Fig. IV-3):

(1) <u>Boulder-Cobble Habitat</u>: This habitat, prevalent at Daisy and Coquille Banks, was characterized by supporting most of the rosethorn, sharpchin, and pygmy rockfish we sampled, as well as lingcod and juvenile rockfish. Sharpchin and pygmy rockfish were clearly the dominant fishes in this particular habitat, attaining nearly uncountable densities in often mixed-species aggregations within 2 m (7 ft) of the bottom. Rosethorn rockfish were more ubiquitous over all rocky bottoms, usually sitting on the bottom. Lingcod were also usually sitting on the bottom when encountered by the submersible, and juvenile rockfish formed spectacular

Table IV-2. Fish taxa used in canonical correlation analysis and subsequent analyses, listed by total number of individuals observed at all three banks in 1990. See text for criteria by which these taxa were selected. Note that not every individual fish listed here were used in the canonical correlation analysis, only those for which we had corresponding bottom-type data (97.7% of all fish sampled).

	Total number of fish observed			
Taxon	All Banks	Daisy	Heceta	Coquille
Pygmy rockfish (*Sebastes wilsoni*)	115498	43273	13101	59124
Sharpchin rockfish (*Sebastes zacentrus*)	16320	4822	3486	8012
Juvenile rockfish (*Sebastes* spp.)	13896	6492	829	6574
Rosethorn rockfish (*Sebastes helvomaculatus*)	6447	2411	722	3314
Greenstriped rockfish (*Sebastes elongatus*)	1115	210	292	613
Dover sole (*Microstomus pacificus*)	849	15	201	633
Sculpins (Cottidae)	813	122	419	272
Slender sole (*Lyopsetta exilis*)	501	21	72	408
Poachers (Agonidae)	470	8	183	279
Shortspine thornyhead (*Sebastolobus alascanus*)	236	1	149	86
Sablefish (*Anoplopoma fimbria*)	412	0	26	386
Rex sole (*Glyptocephalus zachirus*)	380	10	85	285
Eelpouts (Zoarcidae)	348	3	135	210
Yellowtail rockfish (*Sebastes flavidus*)	252	0	252	0
Lingcod (*Ophiodon elongatus*)	78	29	11	38

Also encountered in this habitat, but only at Daisy Bank, were numerous ratfish in the process of laying egg cases, which were scattered over the bottom.

(2) Mud Habitat: This habitat, prevalent in the deeper regions of Coquille and Heceta Banks, was characterized by an assemblage of mud specialists (in order of decreasing loadings): Dover sole, rex sole, agonids (poachers), zoarcids (eelpouts), shortspine thornyhead, greenstripe rockfish, and sablefish. When encountered by the submersible, fish of all these species were sitting on the mud bottom, except sablefish, which actively swam within a few meters of the bottom. All these species tended to be evenly and sparsely distributed over mud bottoms, except greenstripe rockfish, which were invariably associated with small patches of rock surrounded by mud, and sablefish, which occurred in schools. Also present yet relatively uncommon were hagfish, ratfish, and skates. Ratfish usually hovered within a meter of the bottom, whereas skates usually lay on the bottom. We observed hagfish in burrows with their heads extended, or curled on the bottom, or occasionally actively swimming.

(3) Rock-Ridge Habitat: This bank-top habitat, occurring only on the shallowest parts of Heceta and Daisy Banks, was characterized by supporting most of the cottids (sculpins) and yellowtail rockfish we observed. Yellowtail rockfish, which we observed only at Heceta Bank, formed schools of hundreds of fish within 3 m (10 ft) of the bottom (and sometimes well off the bottom above

the sub) or sat on the bottom (see Chapters 3 and 5). Sculpins were fairly evenly distributed, and invariably sat on the bottom.

Among-Bank Comparisons

<u>Differences in Fish Assemblages</u>: Even at a coarse scale of resolution, the overall rank abundances of the 14 most abundant and/or commercially valuable species we examined (listed in Table IV-2) were significantly different among banks (Kendall's coefficient of rank concordance=0.476, P=0.001, df=2).

The most striking differences were that yellowtail rockfish were observed only at Heceta Bank, and no sablefish were seen at Daisy Bank. However, our missing these species does not necessarily mean that they were absent. First, commercial fishermen reportedly catch yellowtail rockfish at Coquille Bank, but only from November to April (Barss, personal communication). Second, we sampled little mud at Daisy Bank, which is the predominant habitat for sablefish elsewhere (see below).

At a finer scale of resolution, the variate scores of our canonical correlation analysis are essentially composite variables that combine all bottom-type variables or all fish species by habitat patch. Therefore, examining among-bank variation in the CCA scores provided truly community-level comparisons among banks.

Kruskal-Wallis tests (nonparametric analogs of one-way analyses of variance) of the CCA variate scores for bottom type and fishes on all three axes (i.e., six analyses) detected highly significant differences among banks in every case (P<<0.001, Table IV-3). That is, the banks differed significantly from each

Table IV-3. Kruskal-Wallis one-way analyses of variance on CCA variate scores among Daisy, Heceta, and Coquille Banks in 1990. Canonical variate scores were derived from canonical correlation analysis of habitat patches (n = 915, see table in caption to Fig. IV-2).

CCA Axis	Variable set	Kruskal-Wallis statistic	P	
1	Habitat	277.6	0.00	***
	Fish	228.1	0.00	***
2	Habitat	80.5	0.00	***
	Fish	133.7	0.00	***
3	Habitat	206.8	0.00	***
	Fish	95.4	0.00	***

*** = P < .001

other in their associations of both bottom types and fish
assemblages.

The significant differences in fish assemblages among banks
were due to differences in the relative abundances of specific
taxa within each general habitat type (Fig. IV-5):

(1) Boulder-Cobble Habitat: This habitat comprised mostly
bottom-type codes BB, BC, BS, CB, and CM. All five fish taxa
that loaded heavily on this first CCA axis varied substantially
between banks over some of these bottom types. Rosethorn
rockfish over all five boulder-cobble bottom types were more than
twice as abundant at Daisy Bank (sometimes over 1,000/hectare)
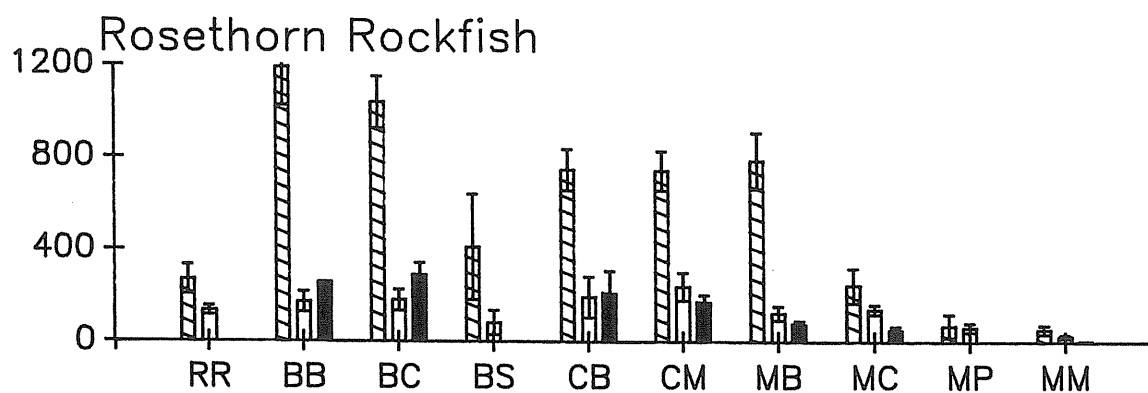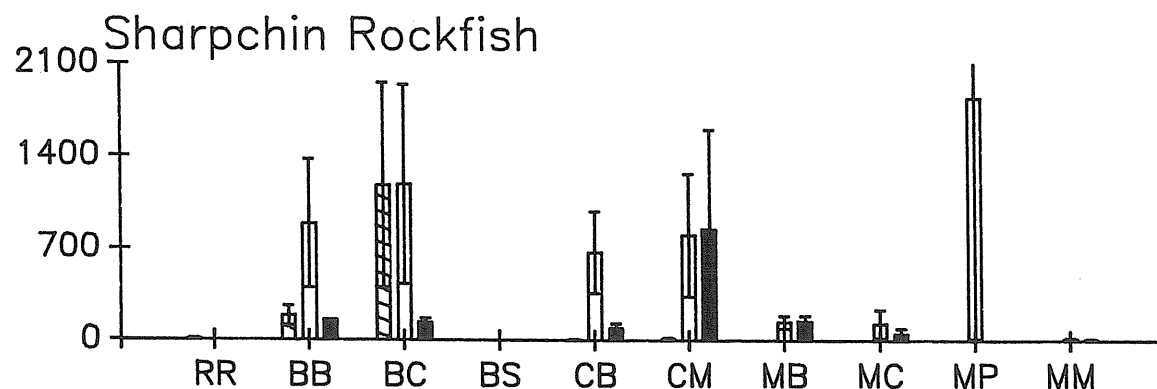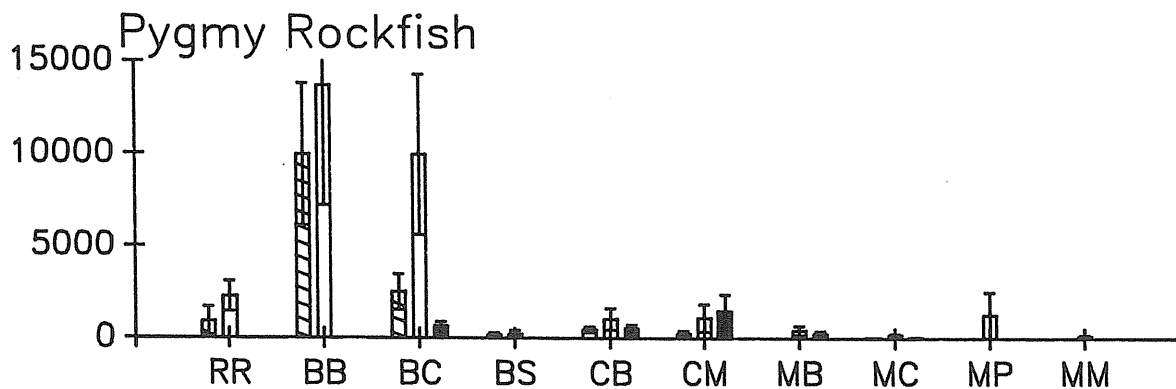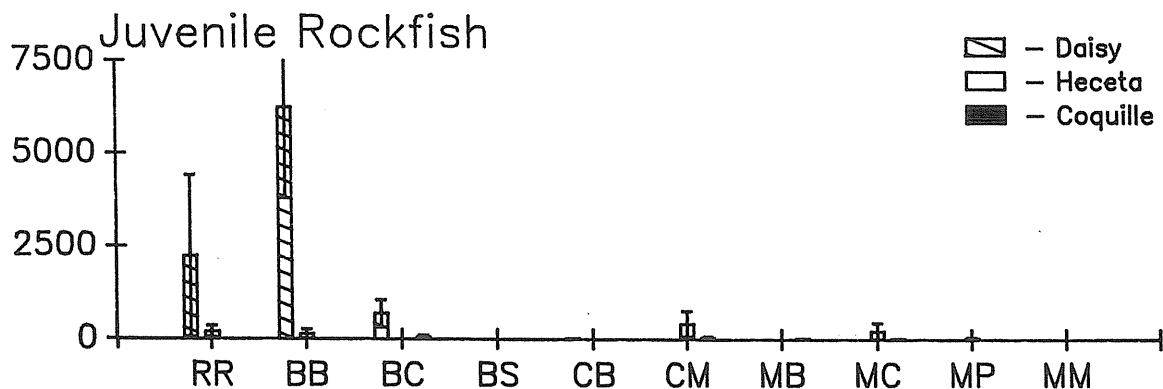than the other two banks, which were nearly equal.

In contrast, sharpchin rockfish showed no consistent
differences among bottom types, although this species tended to
be most abundant at Heceta Bank. Over pure boulders (BB) and
cobble with boulders (CB), sharpchins were several times more
abundant at Heceta Bank (up to about 1,000/hectare) than the
other two banks, which were nearly equal. Over boulders with
cobble (BC), sharpchins were equally abundant at Heceta and Daisy
Banks (over 1,000/hectare), and about an order of magnitude less
abundant at Coquille Bank. Over cobble with mud (CM), sharpchins
were equally abundant at Heceta and Coquille Banks, and over an
order of magnitude less abundant at Daisy Bank.

Pygmy rockfish also tended to be most abundant at Heceta
Bank. Over BB bottoms, pygmies were about equally abundant at
Heceta and Daisy Banks (nearly 15,000/hectare), yet were absent
at Coquille Bank. Over BC bottoms, pygmies were several times
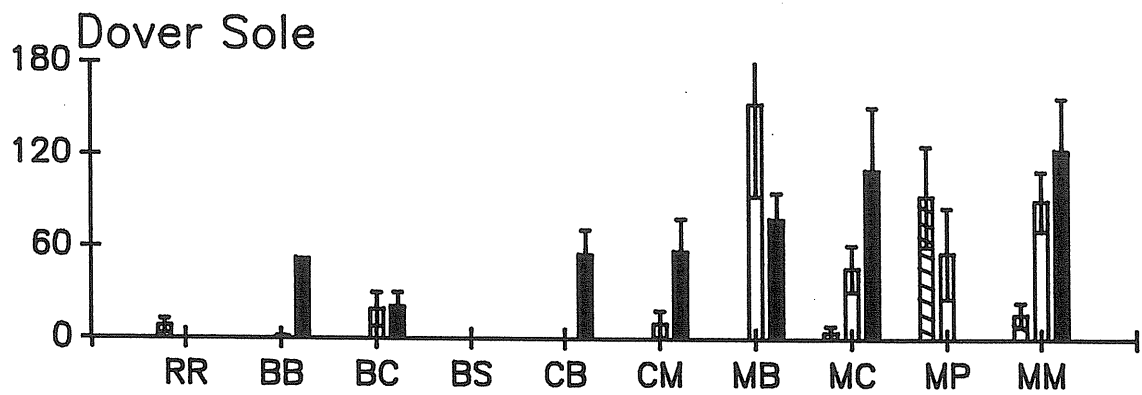
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Figure IV-5. Densities (mean number/hectare $\pm$ 1 SE) of 14 selected fish taxa among the ten dominant bottom types at Daisy, Heceta, and Coquille Banks in 1990 (n = 915, see table in caption to Fig. IV-2).

Density (number/Hectare)
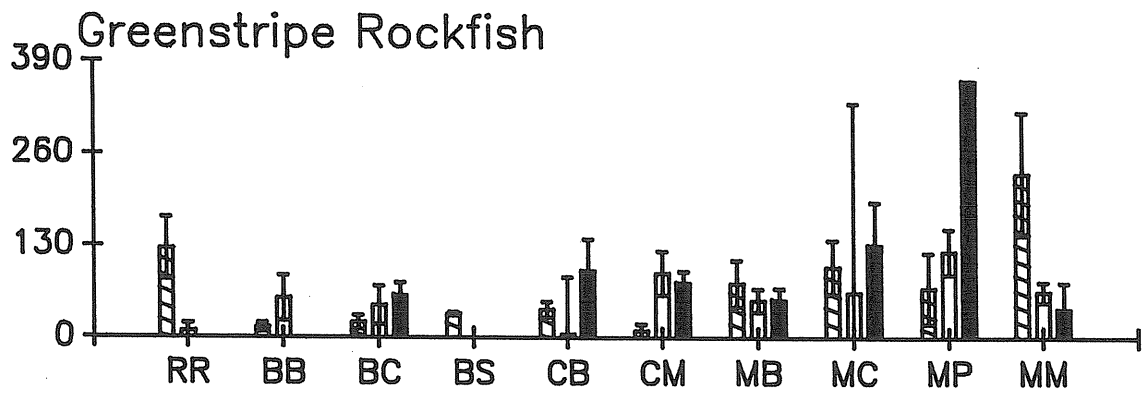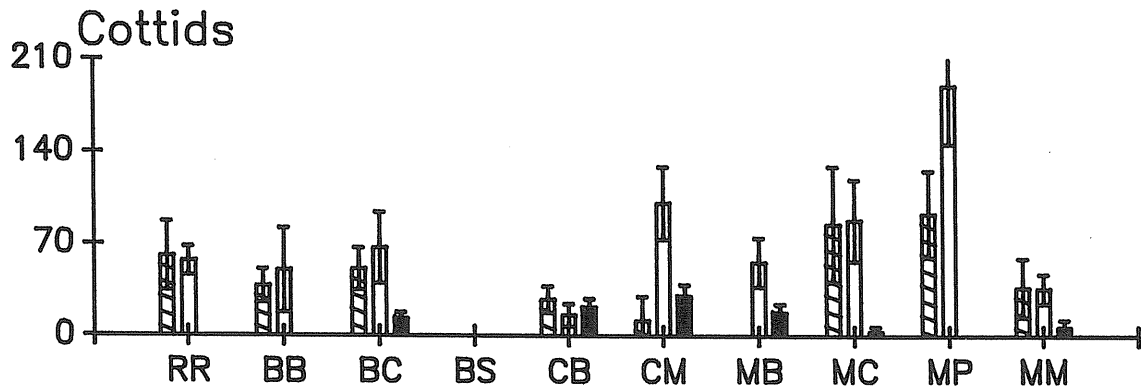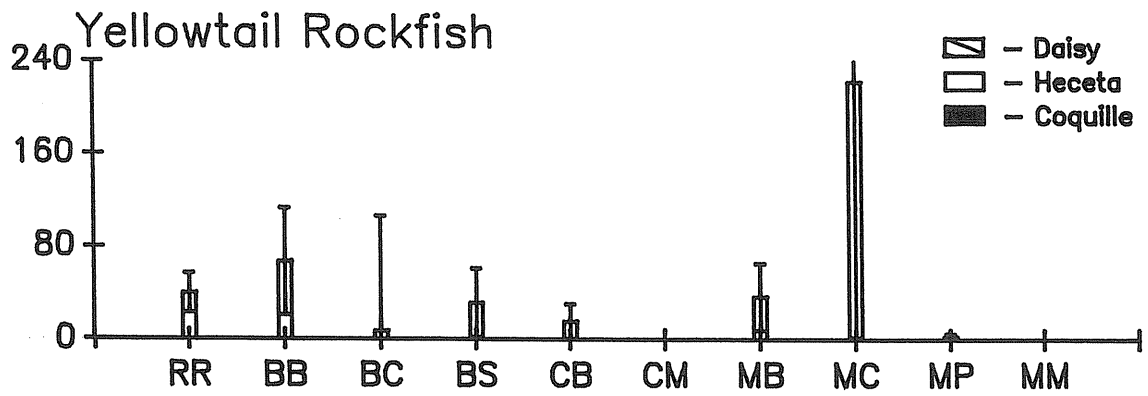
Yellowtail Rockfish

Daisy
Heceta
Coquille

RR BB BC BS CB CM MB MC MP MM

Cottids

RR BB BC BS CB CM MB MC MP MM

Greenstripe Rockfish

RR BB BC BS CB CM MB MC MP MM

Dover Sole

RR BB BC BS CB CM MB MC MP MM
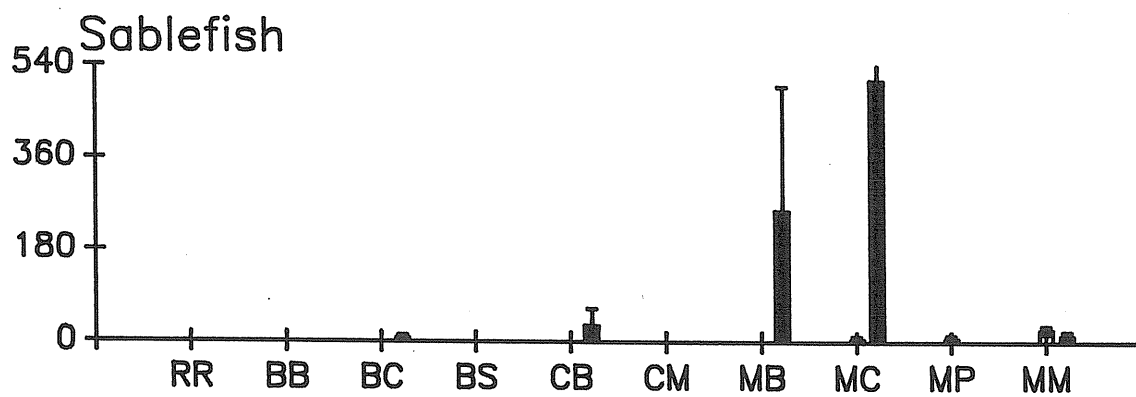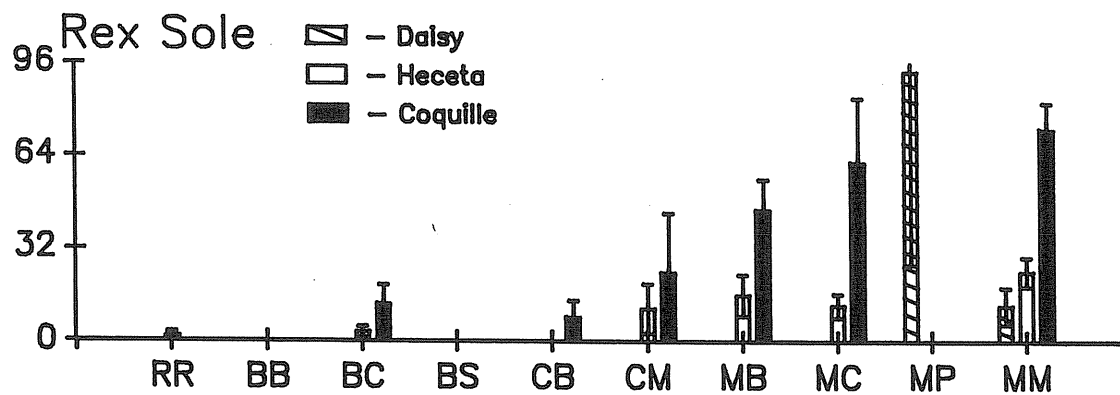
Bottom type (by bank)

128

more abundant at Heceta Bank (about 10,000/hectare) than the other two banks, which were nearly equal.

Juvenile rockfish occurred mostly over pure boulders (BB). Over this bottom type, they were most abundant at Daisy Bank (over 6,000/hectare), over an order of magnitude less abundant at Heceta Bank (about 200/hectare), and virtually absent at Coquille Bank. Note, however, that 1990 was a poor year for juvenile rockfishes at Heceta Bank; many more were observed in 1989 than 1990 (Chapter 3).
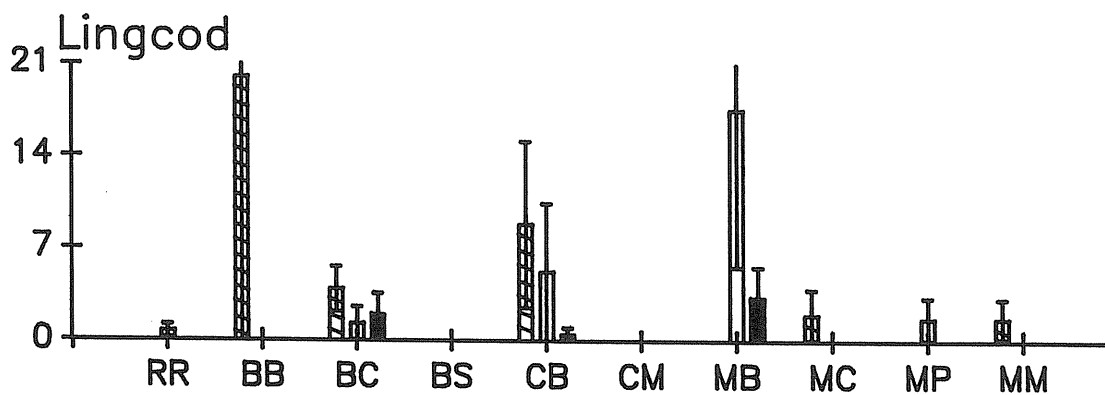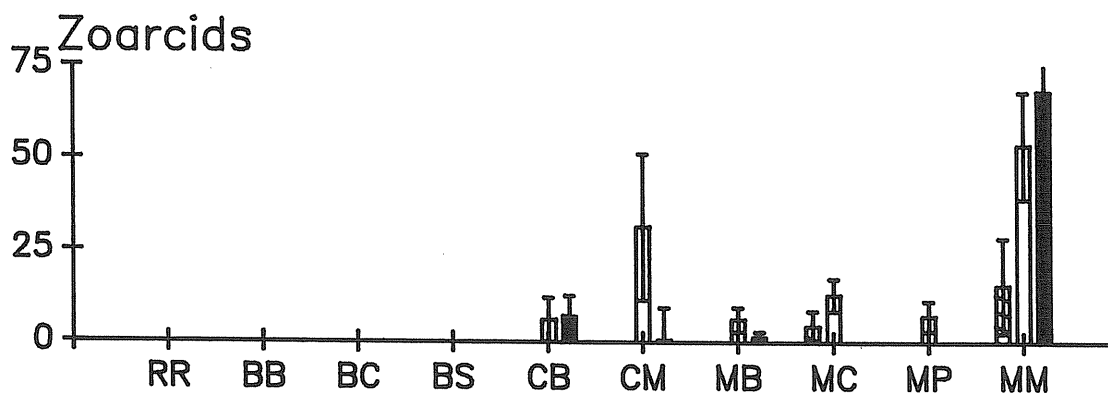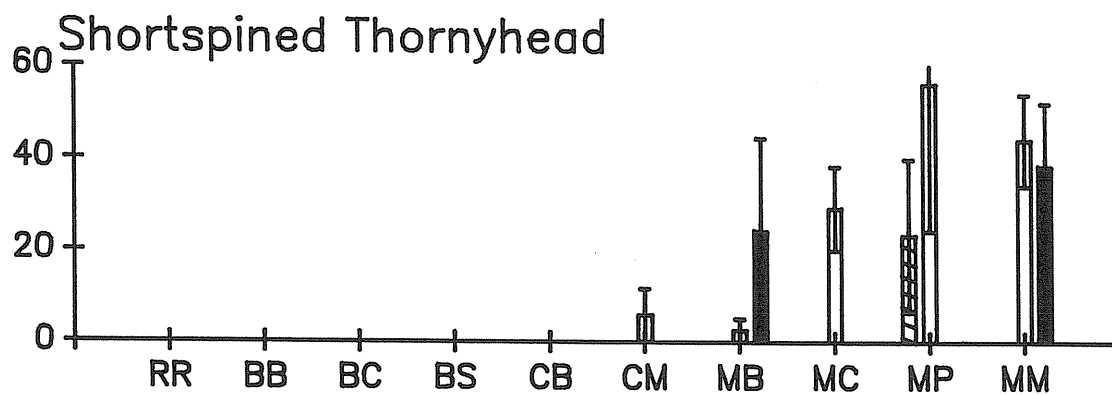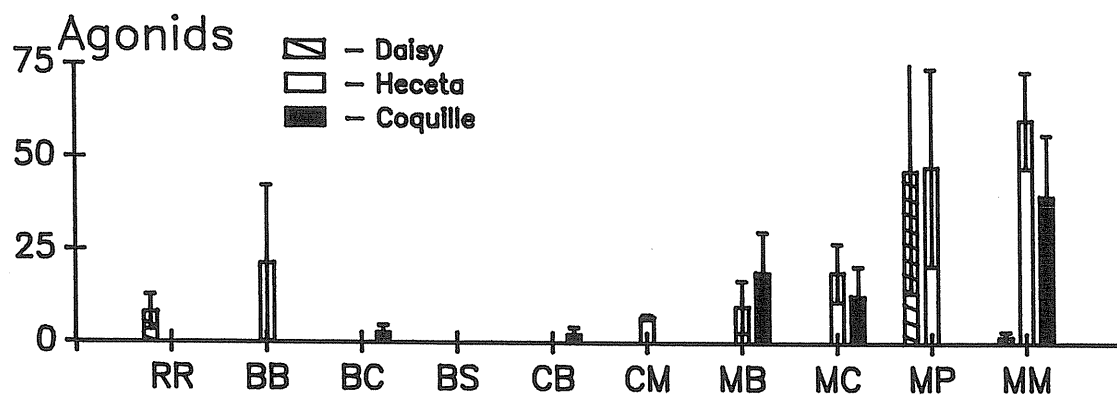
Lingcod reached their greatest densities among banks (about 20/hectare) on pure boulders (BB) at Daisy Bank. We observed no lingcod on this bottom type at the other two banks in 1990, although lingcod occurred mostly on this bottom type at Heceta Bank in 1989 (Chapter 3). There were no striking among-bank differences in lingcod densities over other boulder-cobble bottoms.

(2) Mud Habitat: This habitat comprised mostly bottom types MM, MP, MC, and MB. All seven fish taxa that loaded heavily on this second CCA axis varied substantially between banks on some of these bottom types. Dover sole and rex sole on all four mud-dominated bottoms tended to be most abundant at Coquille Bank. There were two notable exceptions to this trend. First, on mud-pebble bottoms (MP), both species were most abundant at Daisy Bank, rex sole reaching their highest overall density there (nearly 100/hectare). Second, on mud-boulder bottoms (MB) at Heceta Bank, Dover sole reached their highest overall density (over 150/hectare). Considering other flatfishes, Coquille Bank

was the only bank where Pacific halibut were observed during transect dives, although rare individuals were sighted during other dives at the other two banks.

Shortspine thornyhead, agonids (poachers), and zoarcids (eelpouts) tended to be equally abundant at Heceta and Coquille Banks, but rare at Daisy Bank, where we sampled little mud. Thornyheads and agonids reached their greatest densities (both about 60/hectare) at Heceta Bank, thornyheads on MP bottoms and agonids on pure mud (MM). Zoarcids reached their greatest density on pure mud at Coquille Bank (nearly 75/hectare).

Greenstripe rockfish and sablefish exhibited the least and most distinctive differences, respectively, among banks on mud-dominated bottoms. Greenstripe rockfish differed among banks only in that they were substantially more abundant on MP bottoms at Coquille Bank (nearly 400/hectare), and on MM bottoms at Daisy Bank (about 250/hectare), compared the other two banks. Sablefish, on the other hand, were common only at Coquille Bank, where they reached densities of over 500/hectare over MC bottoms. Sablefish were relatively rare at Heceta Bank, and none were observed during transects at Daisy Bank.

(3) Rock-Ridge Habitat: One of the two fish taxa that loaded heavily on this third CCA axis varied substantially between banks. Recall that we did not observe this habitat, dominated by rocky ridges (RR), at Coquille Bank. On one hand, cottids (sculpins) reached nearly equal densities of about 60/hectare at Daisy and Heceta Banks. On the other hand, yellowtail rockfish

were observed only at Heceta Bank. See Chapters 3 and 5 for more information on this species.

Differences in Fish Lengths: We compared the size distributions among banks of 12 of the 14 fish taxa we analyzed in the canonical correlation analysis (Table IV-4). (Recall that yellowtail rockfish occurred only at Heceta Bank, and that juvenile rockfish were in the 0-1 dm [0-4 in] size class by definition.)

One-way analysis of variance (ANOVA) detected no significant differences among banks in the size distribution of four taxa (P>0.05, Table IV-4): rex sole, shortspine thornyhead, sharpchin rockfish, and poachers. The eight remaining taxa exhibited significantly different sizes among banks (P<0.05, Table IV-4). Figure IV-6 and Table IV-4 compare the size distributions and mean sizes, respectively, of these taxa among banks, presented here by predominant habitat:

(1) Boulder-Cobble Habitat: Pygmy rockfish were slightly larger at Coquille Bank than at the other two banks, whereas rosethorn rockfish were slightly smaller at Daisy Bank than at to the other two banks. Lingcod exhibited the greatest among-bank differences in length, being largest at Daisy Bank (some exceeding a meter in length), of moderate size at Heceta Bank, and smallest at Coquille Bank.

(2) Mud Habitat: Greenstripe rockfish were slightly larger at Coquille Bank than at the other two banks, whereas Dover sole

Table IV-4. Average total length of fishes observed at Daisy, Heceta, and Coquille Banks in 1990. P values are for one-way analyses of variance of fish length (dm TL) among banks. [n] = the total number of observations made per species and bank. Dashes indicate species that were not observed at particular banks. Size-class distributions for the eight significant species are in Figure IV-6.

| | Average fish length (dm TL) [n] | | | |
	Daisy	Heceta	Coquille	P
Pygmy rockfish	1.4 [618]	1.3 [392]	1.7 [969]	0.00 ***
Rosethorn rockfish	1.7 [1586]	2.0 [630]	2.0 [745]	0.00 ***
Greenstripe rockfish	2.2 [169]	2.3 [250]	2.5 [317]	0.00 ***
Dover sole	2.3 [15]	2.9 [252]	2.4 [481]	0.00 ***
Lingcod	8.3 [29]	7.2 [11]	6.0 [9]	0.00 ***
Sablefish	---	4.9 [35]	4.6 [71]	0.04 *
Zoarcids	1.3 [3]	2.3 [174]	2.6 [145]	0.00 ***
Cottids	1.4 [118]	1.1 [339]	1.4 [139]	0.00 *
Rex sole	2.1 [9]	2.2 [392]	2.2 [969]	0.95 NS
Shortspine thornyhead	2.0 [1]	1.7 [173]	2.2 [58]	0.69 NS
Sharpchin rockfish	1.9 [126]	2.0 [191]	2.0 [591]	0.22 NS
Agonids	1.5 [8]	1.8 [297]	1.8 [120]	0.09 NS
Yellowtail rockfish	---	4.3 [63]	---	---

*** P < .001
  * P < .05
 NS = Not significant (P > .05)

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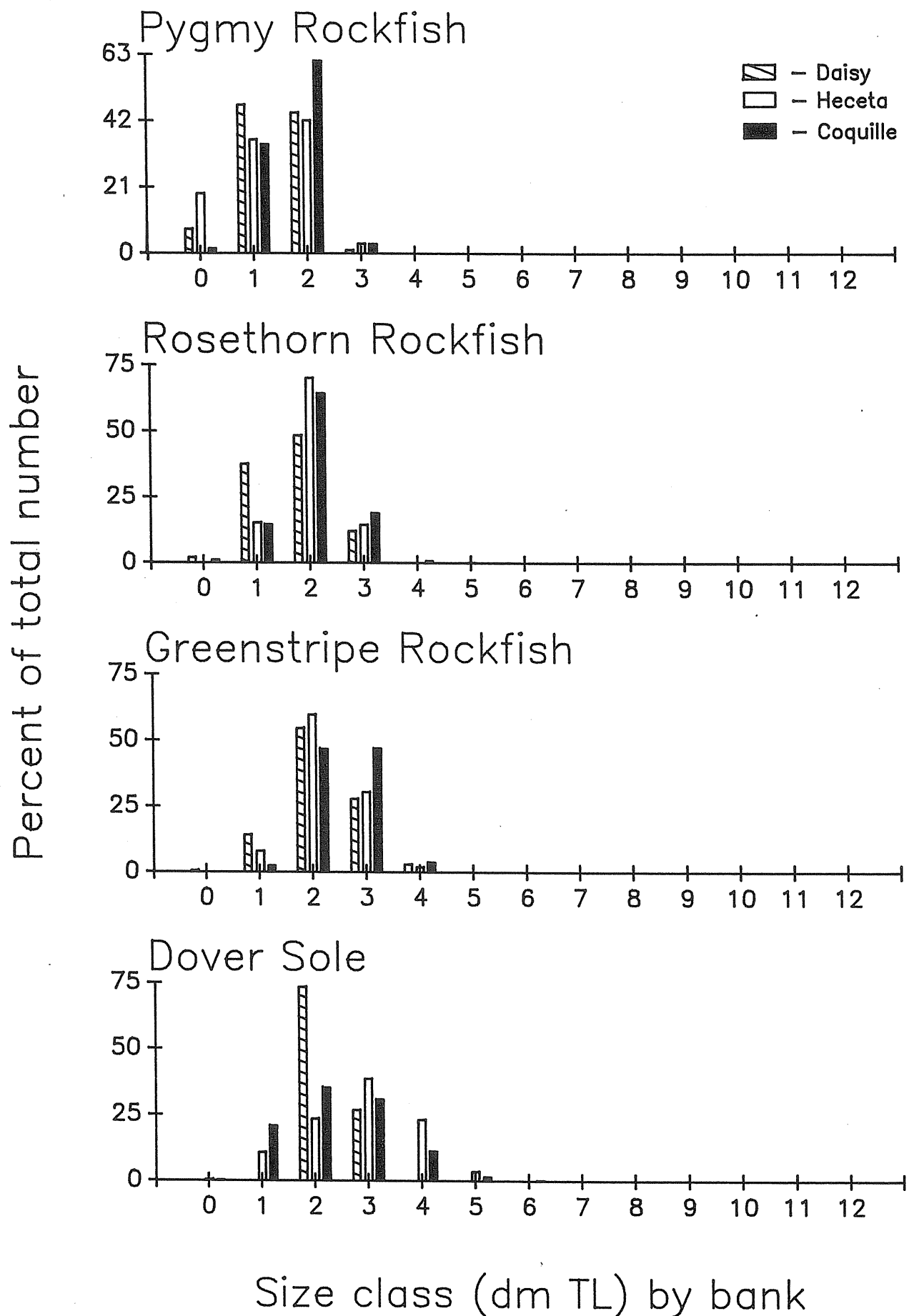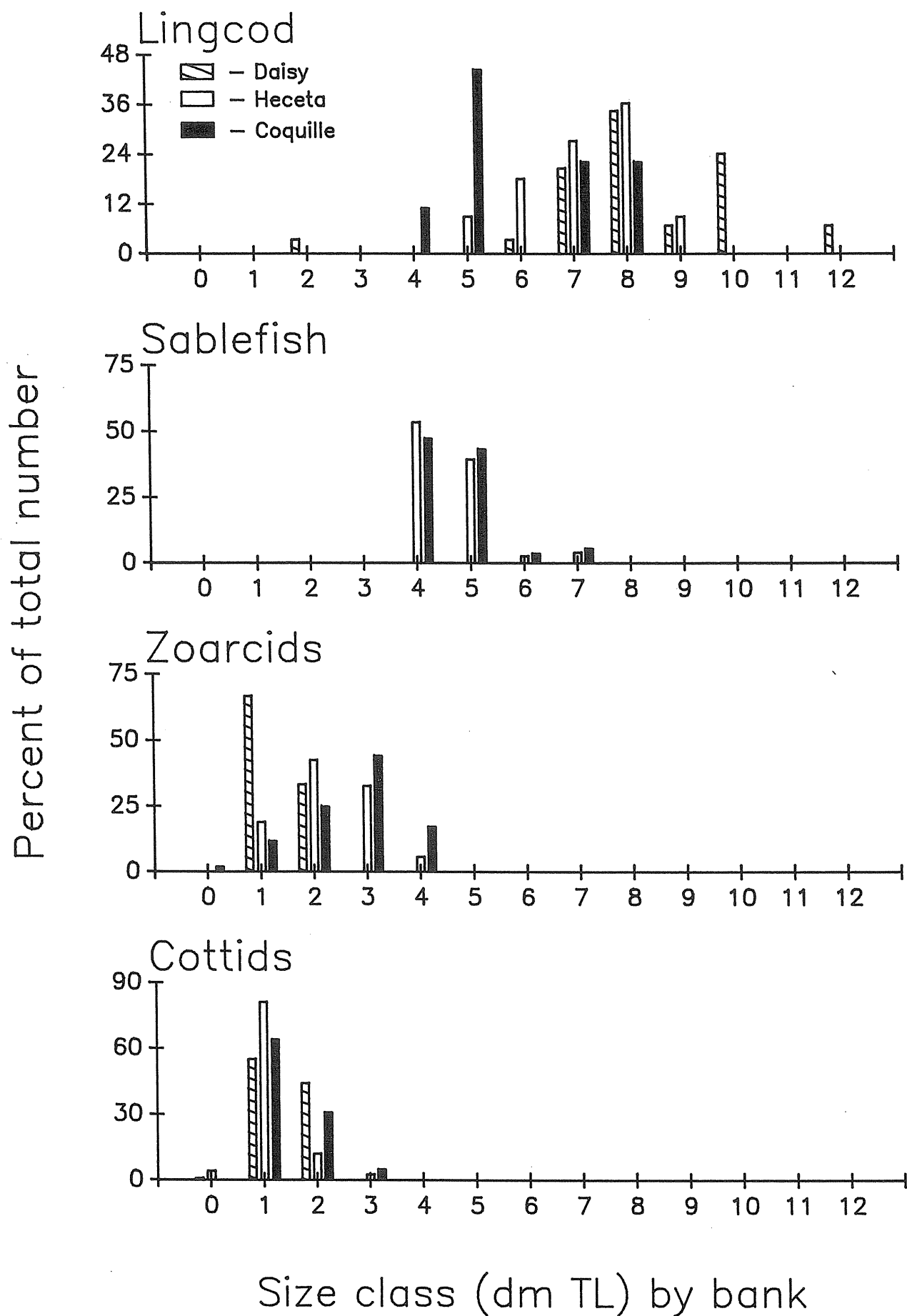Figure IV-6. Size-class distributions of fishes displaying significant differences in total length (dm TL) among Daisy, Heceta, and Coquille Banks in 1990. Average fish lengths for each bank and statistical tests are in Table IV-4.

Pygmy Rockfish

Rosethorn Rockfish

Greenstripe Rockfish

Dover Sole

Percent of total number

Size class (dm TL) by bank

Daisy
Heceta
Coquille

Size class (dm TL) by bank

were slightly larger at Heceta Bank than at the other two banks. Sablefish were slightly larger at Coquille Bank than at Heceta Bank (and were not observed during transects at Daisy Bank). Zoarcids (eelpouts) were slightly larger at Coquille Bank than at the other banks, and smallest at Daisy Bank.

(3) <u>Rock-Ridge Habitat</u>: Cottids (sculpins) were slightly smaller at Daisy Bank than at the other banks.

Over all habitats, for the six taxa exhibiting clear differences among banks, three were largest at Coquille Bank (pygmy rockfish, greenstripe rockfish, and zoarcids), two were largest at Heceta Bank (Dover sole and sablefish), and one was largest at Daisy Bank (lingcod). There was an overall tendency for Daisy Bank to support the smallest rockfishes.

Synthesis and Discussion

There are three major habitats for demersal fishes at Daisy, Heceta, and Coquille Banks. Each habitat is prevalent at two of the banks, and each for a different pair of banks, providing all possible ecologically meaningful pairwise comparisons of fish assemblages:

(1) <u>Boulder-Cobble Habitat</u>: This habitat is most prevalent at Daisy and Coquille Banks, but also present at Heceta Bank. It is characterized by supporting most of the rosethorn, sharpchin, and pygmy rockfish we sampled, as well as lingcod and juvenile

rockfish. All five of these taxa varied substantially between banks in 1990.

Because this habitat was dominated by several species of rockfishes, we expected but did not observe the substantial microhabitat partitioning among species noted on shallower reefs (e.g., Larson 1980b; Hallacher and Roberts 1985). On the contrary, rosethorn rockfish were virtually everywhere on all rocky bottom types, and pygmy and sharpchin rockfishes co-occurred in dense mixed-species aggregations over boulder-dominated bottoms. These patterns suggest one of two possibilities: (1) that competition among these species has been important, but they partition food as opposed to space or coexist by some other mechanism; or (2) that competitive interactions may not be important among these species, even though shallow-water species have been shown experimentally to compete (Larson 1980b).

Considering possibility (1), co-occurring rockfishes in previous studies tended to partition space much more than food (e.g., Larson 1980b; Brodeur and Pearcy 1984; Hallacher and Roberts 1985), yet spatial partitioning was not evident in our study. One intriguing way that rockfishes may coexist without resource partitioning despite ongoing competition would be if isolated rocky banks follow Pulliam's (1988) "sources and sinks" model of community structure. This model, which formalized earlier hypotheses by Dale (1978) and Abrams (1984), suggests that any locality is simultaneously a "source" for some species, which produce excess larvae that settle in other localities, and a "sink" for other species, which settle from other sources. In any one locality, a sink species may be an inferior competitor,

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but is saved from local extinction by a steady replenishment of larvae from a source locality for that species. Thus, this model provides a mechanism whereby competing species may be able to coexist indefinitely without partitioning resources. For example, it may be that a source locality for rosethorn rockfish is Daisy Bank, where this species attains its greatest densities among banks. This hypothesis may explain the ubiquity of rosethorns over all rocky bottoms at all banks.

If the different rocky banks of the Pacific Northwest act as sources for different species, then each bank is important for maintaining these species regionally. In such cases, overfishing one bank may affect rockfish populations on distant banks.

Considering possibility (2), it is possible to elicit many specific hypotheses on why resources may not be limiting for deep-reef rockfishes (reviewed by Ebeling and Hixon 1991). In any case, the mechanism would be mortality before and/or after settlement that keeps populations from reaching densities where resources become limiting. The most likely processes involved would be physical disturbance, environmental harshness, starvation, or predation while the larvae are in the plankton (review by Bailey and Houde 1989), and predation of juveniles after settlement (review by Hixon 1991).

Both juvenile rockfish and lingcod reached their greatest densities among banks over pure boulder bottoms at Daisy Bank, which was also where lingcod reached their greatest size. We hypothesize that lingcod, which prey on small fish, may survive to large size in areas where juvenile rockfishes are abundant as a source of food.

Coquille Bank supported few juvenile rockfish, perhaps because it was strongly influenced by mud (see below). Heceta Bank supported few juvenile rockfish in 1990, but many in 1989 (Chapter 3). Therefore, the distribution of juvenile rockfish at the scale of both local habitats and entire banks is patchy in both time and space. This variability suggests that occasional "recruitment limitation" may occur for rockfishes (review by Doherty and Williams 1988).

At both Daisy and Heceta Banks, juvenile rockfishes were most abundant at shallower depths, especially over pure boulder bottoms. We hypothesize that rockfishes utilize the shallow parts of rocky banks as juvenile nurseries which provide: (1) the closest suitable habitat for larval settlement from the epipelagic plankton; (2) a source of small invertebrate food; and (3) holes, crevices, and large sessile invertebrates for shelter, especially as refuges from predation (see Hixon 1991). This hypothesis is consistent with the observed ontogenetic shift of nearshore rockfishes from shallow to deep habitats as they grow (Love at al. 1991). Straty (1987) and Carlson and Straty (1981) also concluded that rocky pinnacles served as nursery habitat for rockfish off southeastern Alaska. Given the commercial importance of rockfishes, shallow rocky bank habitats may be crucially important "harvest refuges" for replenishing exploited stocks in the region.

(2) Mud Habitat: This habitat, prevalent in the deeper regions of Coquille and Heceta Banks, was characterized by an assemblage of mud specialists: mostly various flatfishes, poachers,

eelpouts, shortspine thornyhead, greenstripe rockfish, and sablefish, with occasional hagfish, ratfish, and skates. All seven of the dominant fish taxa varied substantially between banks, and the most prevalent pattern was that Coquille Bank supported the greatest density mud-bottom fish.

It was clear to us that Coquille was the "muddiest" of the three banks. Unlike Daisy and Heceta Banks, all rocky bottoms at Coquille were covered by a thin layer of silt. At our Station 4 at Coquille (Chapter 2: Fig. II-2), the suspended sediment was so thick that we were unable to run a useful transect (see Appendix 4). Because it is the bank closest to shore, and located directly west of the mouth of the Coquille River at Bandon (Chapter 2: Fig. II-1), we hypothesize that nearshore river-born sediments result in Coquille Bank supporting the greatest density of mud-bottom species.

(3) Rock-Ridge Habitat: This bank-top habitat, occurring only on the shallowest parts of Heceta and Daisy Banks, is characterized by supporting most of the sculpins and yellowtail rockfish we observed in 1990. On one hand, sculpins were equally dense at the two banks. On the other hand, yellowtail rockfish was the only common species that we observed only at Heceta Bank. Thus, rock ridge provided the most striking differences among banks, being a habitat that was altogether absent from Coquille Bank, and that supported yellowtail rockfish only at Heceta Bank.

We hypothesize that yellowtail rockfish occur where we sampled only on Heceta Bank largely because it is the only bank providing shallow, high-relief, rocky ridges, which appear to

provide distinctive outposts for school formation (see Chapter 5). Although the literature reports yellowtail occurring as deep as 550 m (300 fathoms; Alverson et al. 1964; Grinols 1965), Gunderson and Sample (1980) reported that the maximum depth of yellowtail caught in our region was 364 m (200 fathoms). Fully a third of the 2410 yellowtail we sampled from 1988 to 1990 at Heceta Bank occurred at depths less than 90 m (295 ft), and we dove to depths ranging from 67 to 365 m (220 to 1200 ft). The minimum depth we sampled at Daisy and Coquille Banks were 127 m (417 ft) and 97 m (318 ft), respectively, so we suspect that where we dove on these banks did not provide the shallow-water high-relief habitats preferred by this species. However, yellowtail rockfish are reported by commercial fishermen to occur seasonally on Coquille Bank from November to April, being caught at depths of 119 m (390 ft) to 155 m (510 ft) (Barss, personal communication).

Conclusions

We conclude that our null hypothesis of no differences among the fish assemblages of Daisy, Heceta, and Coquille Banks is falsified. Despite overall similarity in the species present at the three banks (with the notable exception of yellowtail rockfish being evident only at Heceta Bank during our study), the relative abundances of species are strikingly different among banks in the three major habitats we sampled. This outcome is not surprising, given the major differences among these banks in location, geology, and general profile.

This conclusion suggests that each of these banks should be managed as a separate entity. This is especially true if the commercially important rockfishes and other species inhabiting these banks act as sources of larvae for replenishing heavily fished areas. Each bank may be an important source locality for different suites of species, such that each bank provides an important "harvest refuge" for sustaining regional fisheries.

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Chapter 5

MOVEMENTS OF YELLOWTAIL ROCKFISH ON HECETA BANK, OREGON

Introduction

Yellowtail rockfish (*Sebastes flavidus*) is a common rockfish along the west coast of North America. It is caught by both commercial and recreational fishermen and was the second most abundant rockfish in Oregon's and Washington's groundfish landings from 1980 to 1986 (Pacific Fisheries Management Council 1987).

Schools of yellowtail rockfish comprising the same individuals may persist at the same location for many years. Carlson (1986) reported that a school of adult yellowtail rockfish in southeastern Alaska consisted of individuals from one or two year-classes and had negligible recruitment over an 11-year period. Because their aggregations may be site specific and interchange of adults limited, and because rockfish are long-lived, late-maturing, and low-fecundity species (Gunderson et al 1980; Love et al. 1990; Eldridge et al. 1991), overfishing or disturbance may have long-lasting effects in a local area. On the other hand, a rockfish species whose individuals move freely from reef to reef may be less vulnerable to perturbations (Love 1979). Thus the structure and stability of rockfish aggregations have important implications for assessment, availability and management of rockfish species.

Yellowtail rockfish is the most abundant large schooling fish over the shallow, rocky areas on the top of Heceta Bank, a deep reef located about 55 km (30 n mi) off the central Oregon

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coast (Figs. V-1 and V-2). Large schools, sometimes of a thousand or more individuals, were observed during submersible dives over shallow portions of the bank (see Chapter 3). Based on both observations from dives and the occurrence of large echo-groups recorded by the ships echosounder, these schools were often associated with pinnacles or high-relief topography (Pearcy et al. 1989).

On one dive the submersible descended into a school of yellowtail rockfish that followed the submersible several hundred meters before abruptly turning and swimming back toward the location where the school was initially encountered (Pearcy et al. 1989). This observation and those of Carlson and Haight (1972), who found that individual rockfish returned to a home site in southeast Alaska after being displaced as far as 22.5 km (12.1 n mi), suggest that schools of yellowtail rockfish may have home ranges centered around a specific site on the bank.

This study used acoustical tracking to determine the horizontal movements and site specificity of yellowtail rockfish, as well as their vertical movements, on Heceta Bank. Yellowtail rockfish is an ideal fish for acoustical tracking because they do not suffer from lethal embolisms of other rockfishes when brought to the surface but instead expel swimbladder gases during decompression.[1]

Methods

Yellowtail rockfish were captured with hook and line, acoustical transmitters were inserted in their stomachs, and they were released immediately, either at the capture site or a

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Figure V-1. Chart showing the location of Heceta Bank. The
hatched area of the bank encompasses the area of this study as
shown in Fig. V-2 (depth contours in meters).

125°30' 125°00' 124°30' 124°00'

Cape
Foulweather

200

Yaquina Head
Newport

44°
30'

44°
30'

2000

Waldport

Heceta
Bank

Heceta
Head

44°

44°

200

Florence

Reedsport

43°
30'

43°
30'

North Bend

Coos Bay
Cape Arago

2000

Bandon
Coquille Pt.

43°

43°

Cape Blanco

Port Orford

125°30' 125°00' 124°30' 124°00'

5   0   5   10   15   20 Nautical Miles

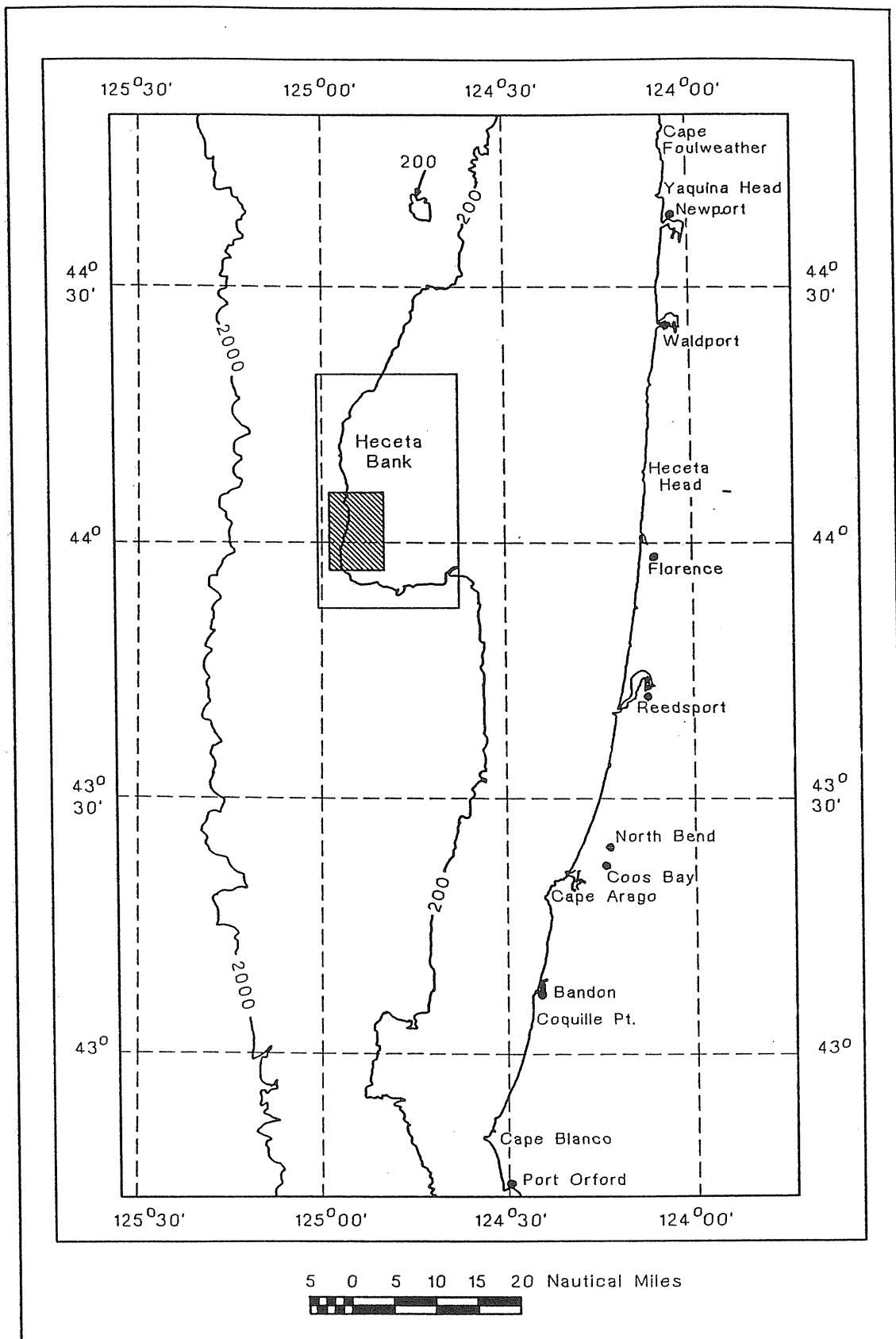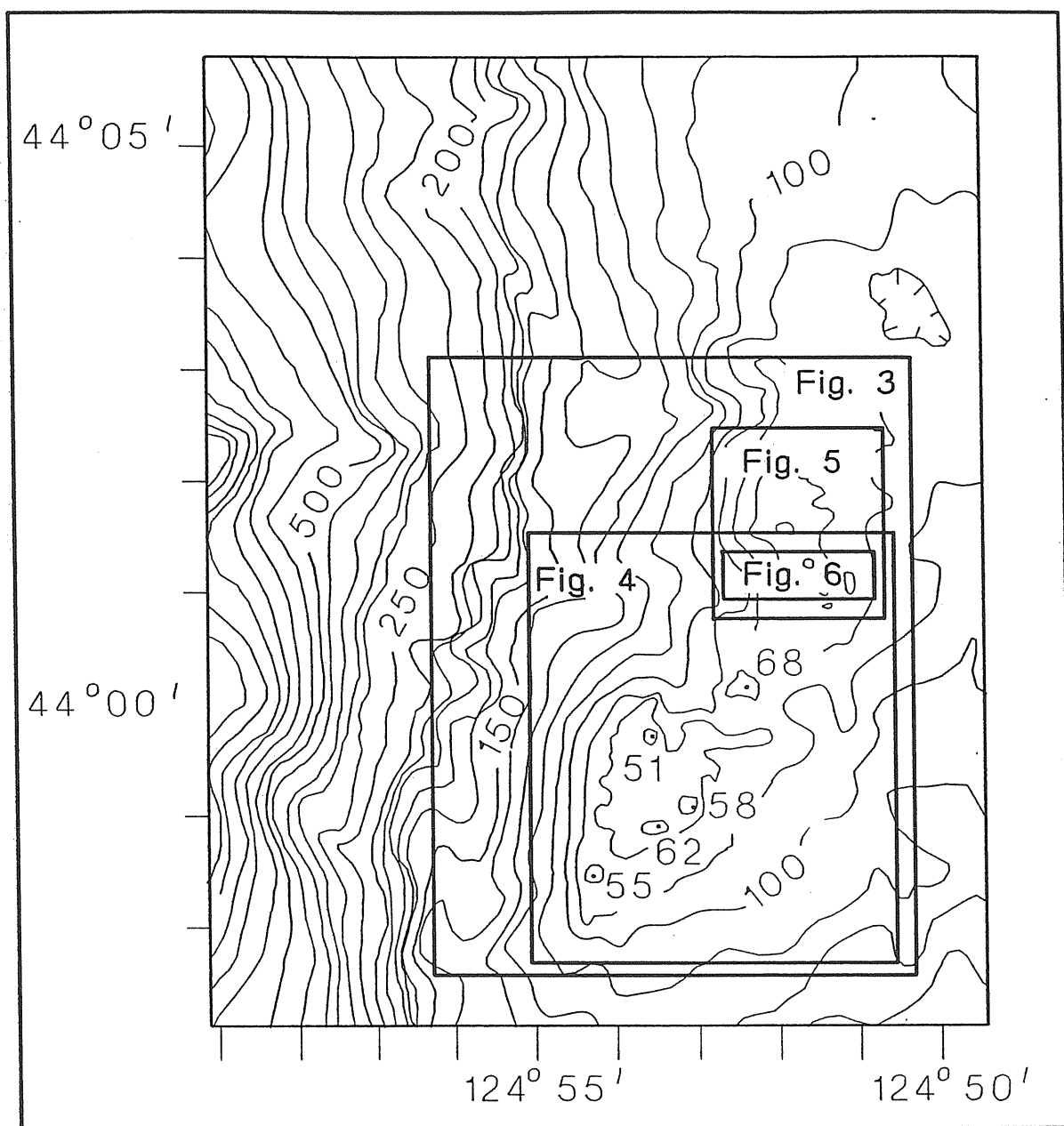Figure V-2. The topography of the southern portion of Heceta Bank and the areas encompassed by each of the following figures. Depths are in meters.

44°05'

200

100

Fig. 3

Fig. 5

500

Fig. 4

Fig.°6₀

250

68

44°00'

150

51

58

62

55

100'

100

124° 55'

124° 50'

151

displaced location, and tracked using a directional hydrophone and acoustical receiver.

Preliminary Tagging: Observations were conducted at sea in tanks aboard ship or in the laboratory to evaluate methods of tagging rockfish. The results of these are summarized in Table V-1. Dummy tags of the same dimensions and weight as the 58 mm (2.3 in) transmitters (Model V3-3HI in Table V-2) were either inserted into the stomach or attached to the side of fish under the dorsal fin. The external tag, similar to the one used by Matthews et al. (in press) for benthic rockfish, caused one fish to list to one side and interfered with its swimming. It died after 3 d in a deck tank at sea. Fish with tags inserted in their stomachs had normal orientation in deck tanks and were more active. One of three fish tagged in this way died after 6 d. Other yellowtail rockfish without any tags also died after several days in tanks with circulating sea water. Yellowtail rockfish, especially those that are over-buoyant from expanded swimbladder gases, became weak after prolonged captivity aboard ship.

Stomach insertion of tags was used in this study. This method is quick and minimizes handling and stress. The major disadvantage was regurgitation of tags (Table V-1 and Results), although Stasko and Pinock (1977) reported that transmitters inserted into the stomachs of many other species were not disgorged. To increase the retention of tags in the stomachs, one or two small (No. 18 steel dry fly) hooks were attached to the ends of tags with epoxy as anti-regurgitation mechanisms (ARM's) during the last year of this study. Hooks protruded 2 mm

Table V-1. Information on tag retention in yellowtail (YT) and
   black (B) rockfishes aboard ship (S) and in the laboratory
   ashore (L). ARM= tags with hooks (anti-regurgitation
   mechanisms).

DATE	SPECIES	S/L	TAG	DAYS TO REGURGITATE (OR DIE)
Sep 1988	YT	S	External	(3)
	YT	S	Stomach	1, 2, (6)
Apr 1990	B	L	Stomach	1
	B	L	Stomach-ARM	9
Jul 1990	B	L	Stomach	0.5
	B	L	Stomach-ARM	2, 89
Aug 1990	YT	L	Stomach-ARM	11

Table V-2. VEMCO ultrasonic transmitters used in this study.

YEAR	TYPE OF TRANSMITTER	SIZE (mm)	BATTERY LIFE (d)
1988	V3-3HI	16 x 58	9
1989	V3-1HI	16 x 48	21
	V3P-1HI	16 x 62	4.5
1990	V3-4HI	16 x 65	64
	V3P-1HI	16 x 62	4.5

(0.08 in) from the tag. In experiments in large aquaria or tanks in the laboratory, tags with ARM's stayed inside either black rockfish (*S. melanops*) or yellowtail rockfish 2, 9, 11 and 89 d compared to 0.5, 1 d for controls without ARM's.

Equipment: VEMCO LTD. acoustical tracking equipment was used in this study, including a VR-60 receiver with preset channel frequencies and a telemetry decoder and display unit, a directional hydrophone, and transmitters with five different crystal-controlled frequencies (Table V-2). Pressure telemetering transmitters were used in 1989 and 1990. The pulse rates of these transmitters were linearly proportional to pressure and individual calibrations were incorporated into the receiver program. According to VEMCO, accuracy was 5% of the full range, or 5 psi (about 3 m or 10 ft). Accuracy of tags lowered vertically on a metered line at sea was similar to that reported by VEMCO. Data on depths of fish and time of day from these transmitters were printed aboard ship as well as stored in the receiver for subsequent analysis. During 1989 depths and times were recorded manually every 5 min or less. During 1990, data were stored by the receiver every 0.5 sec and median depths were calculated for every 25 sec period and plotted by computer.

Non-pressure transmitters were employed in 1988, 1989, and 1990. In 1990, transmitters with the same frequencies had different pulse widths and pulse periods which were decoded and displayed by the receiver. The transmitters had a rated range of 500 to 1500 m (1640 to 4921 ft). Battery life varied from 4.5 d to 60 d depending on the type of transmitter used (Table V-2).

Field Procedures: Research was conducted aboard two vessels--the *R/V William A. McGaw*, a 32-m (105-ft) ship used for submersible research, and the *F/V Corsair*, an 18-m (60-ft) trawler. Echosounders were used to scout for concentrations of fish over the shallow (60-90 m or 197-295 ft) portions of Heceta Bank. When dense midwater schools of fish were detected, weighted fishing lines with jigs were lowered to catch fish. Only yellowtail rockfish were caught from midwater schools which were usually at depths of 20 to 40 m (66 to 131 ft). Often the concentrations of fish were so high that our fishing weights bounced off fish at these depths. If yellowtail rockfish were readily caught, our position was recorded and an anchored surface float was released from the Corsair to assist tracking.

Yellowtail rockfish were placed into deck tanks with circulating sea water after capture. Transmitters were inserted into the stomachs of large (42-54 cm or 17-21 in fork length, mostly males), active fish using a wooden rod, and fish were immediately released at the capture site, or at sites up to 3.7 km (2 n mi) away. The four fish that were tracked in 1988 were also tagged with external Floy tags.

Transmitter signals were detected with the directional hydrophone attached to the end of a 4 m (13 ft) rotatable pole which was mounted to the side of the vessels so that it could be raised when not in use. The hydrophone pole was rotated through 360 degrees until the signal strength of a transmitter was maximal. Then the course of the vessel was adjusted to steam directly toward the transmitter. Signal strength increased as

the range closed. A fix was obtained with LORAN C when signal strength was high in all directions, or when the direction of the signal fell off rapidly to the port or starboard or directly astern. This was the estimated location of the transmitter. Repeated fixes on stationary transmitters on the bottom were within 180 m (0.1 n mi) from each other. Repeatable accuracy of LORAN C for one vessel is about 100 m (328 ft).

Results

Horizontal Movements:

1988-Figure V-3:

Four yellowtail rockfish were caught and released from the *R/V McGaw* on September 13, 1988. Three fish were released where they were caught, and the fourth was released about 2 km (1 n mi) offshore of its catch location.

Fish No. 1 was caught and released over a shallow (71 m or 233 ft), high relief, rocky area of Heceta Bank. Three fixes were obtained after release, three after 12 h and two after about 24 h. All fixes were within 0.9 km (0.5 n mi) of each other, and the last was 0.2 km (0.1 n mi) from the capture site.

Fish No. 2 and 3 were caught and released over the southern-most shallow portion of Heceta Bank where the depth was about 80 m (262 ft). One of these fish was detected about 1400 m (0.75 n mi) east of its capture location after 7 h. The other fish was found within several hundred meters of the release site 17 h after release.

The submersible *Delta*, with a separate hydrophone and receiver, dove on Fish No. 3, which remained close to the release

Figure V-3.   Locations and tracks of yellowtail rockfish tagged
and released in 1988.   Fish No. 1, released September 15 at
1919 hrs (solid circle), was located 24 hrs later (solid
square), and was found within the open circle during seven
intervening fixes.   Fish No. 2, 3 and 4 were released
September 13 (solid circles) and followed indicated paths.
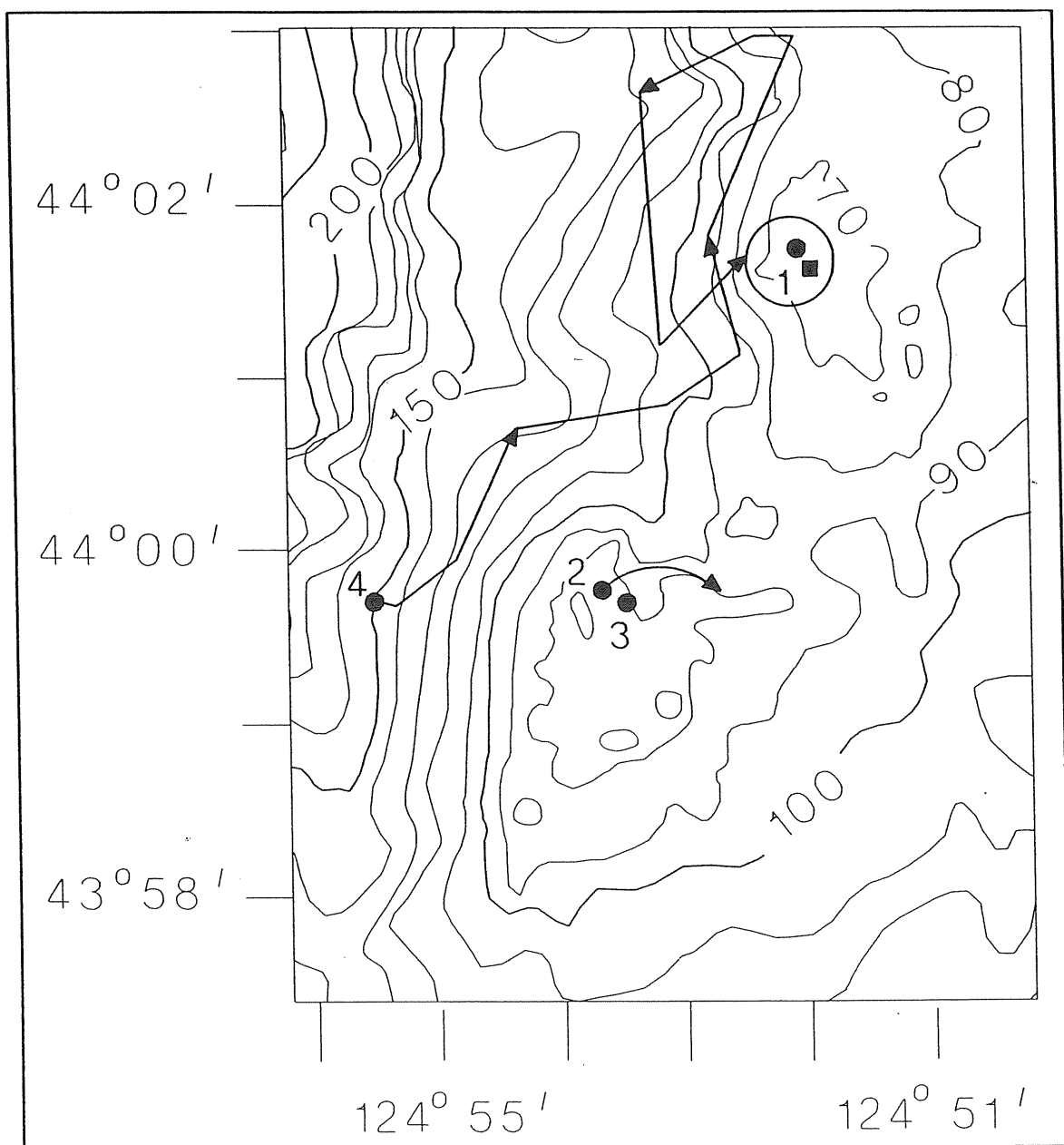
site, to determine if the tag had been regurgitated. The ship maintained position over this transmitter as the submersible was launched. A large school of yellowtail rockfish was observed at this location. Although a strong signal was recorded from the transmitter, its bearing changed frequently, indicating that the tag was moving. This was confirmed when the bearing of the transmitter changed 180 degrees as a school of several hundred fish swam under the submersible. The fish transmitting the signal had two external Floy tags but was not seen.

The fourth fish was captured at the southern high spot of Heceta Bank and released about 2 km (1 n mi) offshore in deep water where the bottom was about 150 m (492 ft). Between 1725 hrs and 0730 hrs the next day, this fish was tracked continuously. It moved to the northeast until 0400, turned south, but then resumed its northeasterly course, ending up near the 75 m (246 ft) depth contour just west of a shallow region of the bank (Fig. V-3).

1989-Figure V-4:

Two experiments were conducted to further investigate horizontal movements in 1989--one involved three fish caught and released with pressure telemetering transmitters at the same location on August 21 or 24. The other included six fish, three of which were released at the capture site and the other three were displaced about a mile away from the capture site on August 25. All fish were caught in midwater where the depth was about 79 m (259 ft).

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Figure V-4. Locations and tracks of yellowtail rockfish tagged and released in 1989. Fish No. 2 was released at site A on August 21 at 1133 hrs; it was subsequently found to the east of the release site but then returned to the area near site A. Two other fish were released at site B on August 24 and remained within the 0.4 km (0.2 n mi) of this release site for 24 hrs. On August 25 six fish were caught at site B and three released there (Fish No. 10, 11 and 12) and three released at site C (Fish No. 7, 8 and 9). During September 3-5, transmitters from Fish 10 and 11 were located near site B. Transmitters in Fish 7 and 9 were found close to release site C. Fish 8 was located east of catch site B.

Fish No. 2 in the first experiment was released at site A and was tracked continuously for 11 h after release. During this time it stayed within about 0.4 km (0.2 n mi) of the release site which was marked by a surface buoy. We returned to this location 36 h later and found this fish 0.9 km (0.5 n mi) to the east. It then returned to release site after 1.5 h and remained in this vicinity for the next 56 h (Fig. V-4).

Two other fish were tagged and released at site B several days later and tracked for about 24 h. These two fish stayed within a diameter of about 0.4 km (0.2 n mi) around the release location during this period.

In the second experiment, six fish were caught at site B. Half were released at the capture location and the remainder were displaced 2.0 km (1.1 n mi) to the northeast and released in 77 m (253 ft) of water at site C. When we returned to these locations 9 d later two of the three tags released at the displaced site C (Fish 7 and 9) were detected there and remained there over the next 36 h. Distinctive double pings were heard on the receiver from these two tags, indicating that the tags were probably on the bottom.

Fish No. 10 and 11 which were released at capture site B were detected just south of site B nine days later. The transmitter from displaced Fish No. 8 was detected about 0.7 km (0.4 n mi) to the east of the capture site. This fish moved progressively closer to the capture location during the next 36 h.

The submersible Delta was used to dive on one of the tags
that was stationary at the displaced location (site C). This
transmitter was found lying on top of a large rock.

1990-Figures V-5 and V-6:

During 1990, transmitters with ARM's were inserted into 12
yellowtail rockfish. All were caught during early evening (1900
h on August 15) in midwater above a 68-m (223-ft) rocky bottom.
Four of these fish were released at capture site A, four 0.9 km
(0.5 n mi) to the north (site B, bottom depth 70 m or 230 ft),
and four 3.7 km (2.0 n mi) to the north (site C, bottom depth 87
m or 285 ft).

The morning after the releases, all four of the transmitters
released at capture site A were detected within 0.2 km (0.1 n mi)
of site A. Fish No. 23 released 0.9 km (0.5 n mi) to the north
returned to the capture site overnight after 17 h. No
transmitters were detected at the other two release sites on the
following day when the ship passed over these locations and
departed the bank.

Eleven of the twelve fish were located 13 d after release
when we returned to Heceta Bank (Fig. V-5), including all four
released at site C 3.7 km (2.0 n mi) to the north. The missing
transmitter was from site B. All 11 of these fish were found at
least once within 0.3 km (0.15 n mi) of the capture site. These
results are evidence for a strong homing tendency.

Two fish that were caught and released at the same location
(site A) showed the most extensive short-term movements. Fish
No. 26 was located 1.5 km (0.8 n mi) and Fish No. 31 was found

Figure V-5.   Tracks of 11 fish caught at site A and released at

sites A (dashed lines), B (dotted lines) and C (solid lines)

on August 15, 1990.   Symbols designate the dates and times

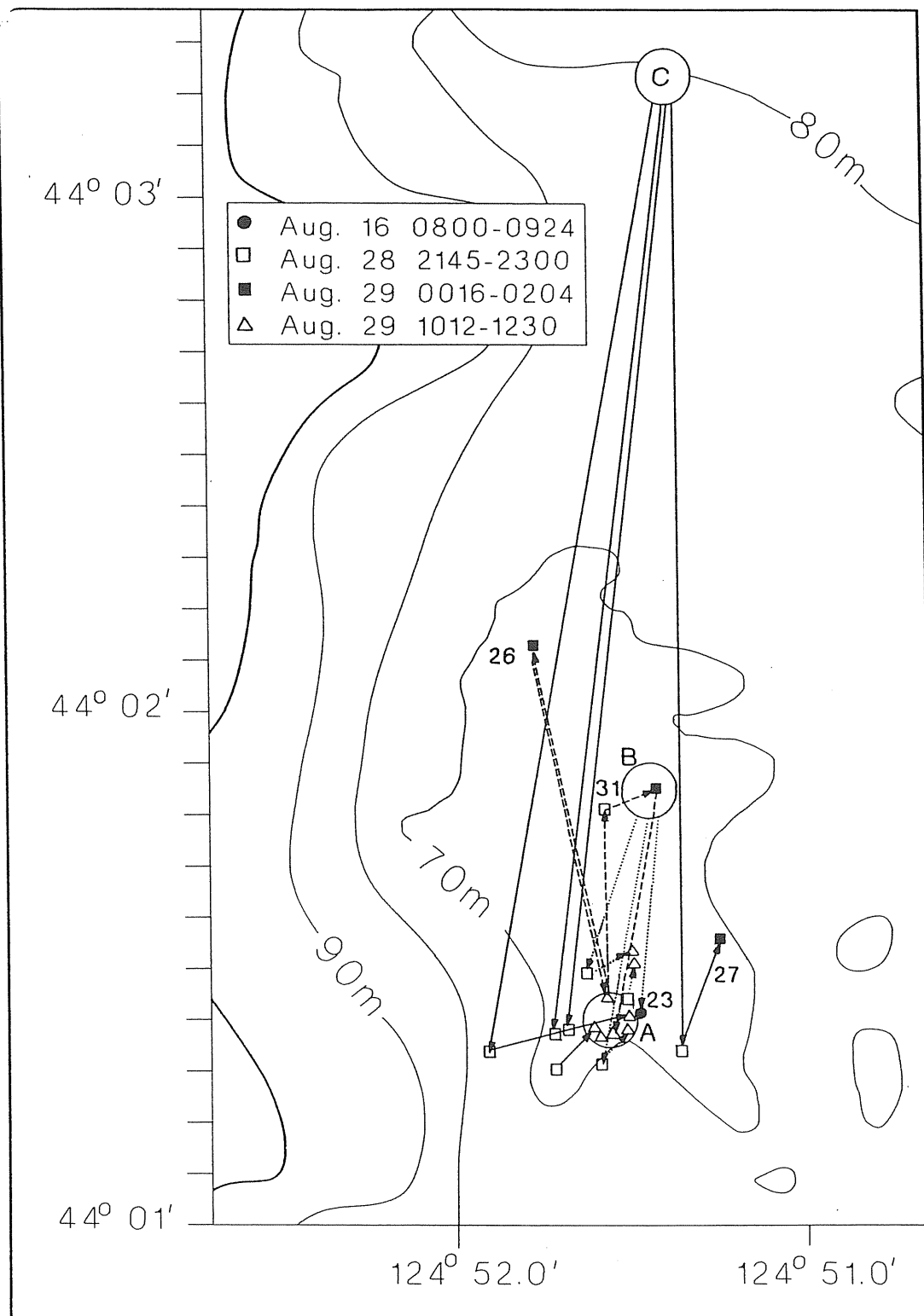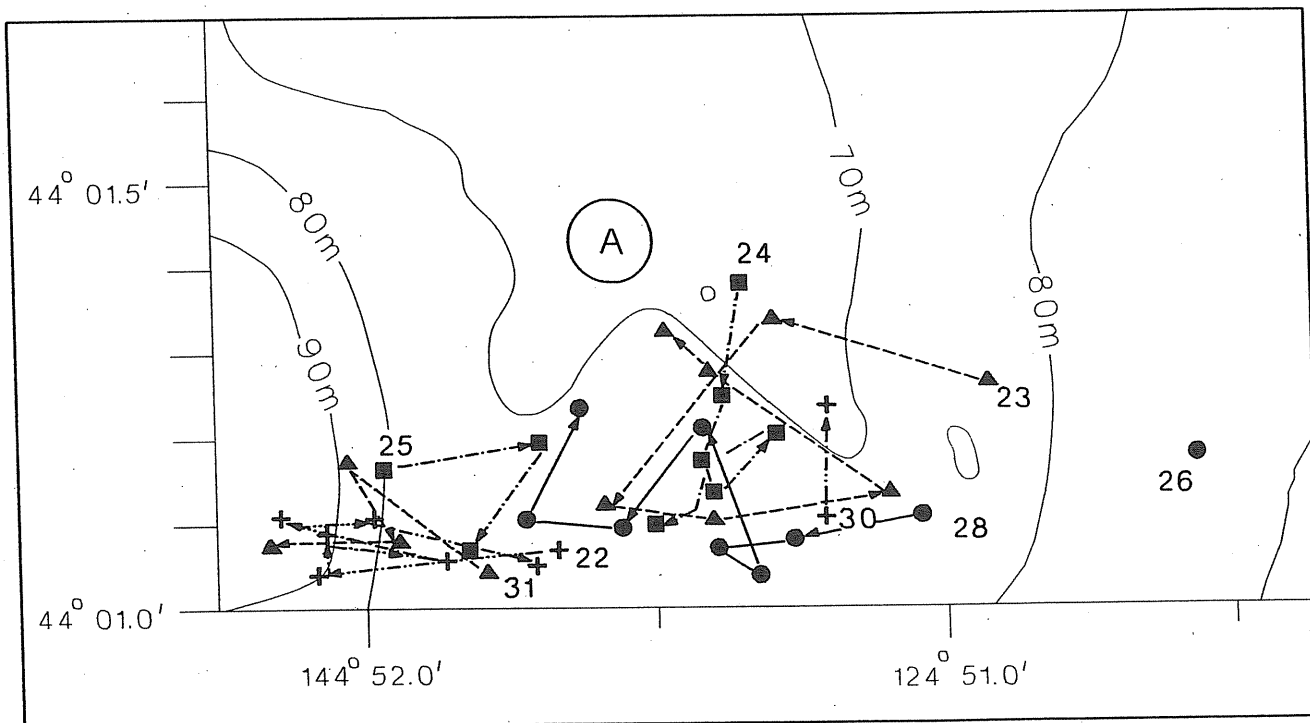that fixes were obtained (see legend).

Figure V-6. Tracks during the period September 16-18, 1990, of

   eight of the yellowtail rockfish tagged and released on August

   15, 1990. Symbols designate location of fixes for each fish.

0.9 km (0.5 n mi) to the north of site A during the night of August 28-29. But both returned to site A by the next day, about 11 h later. Fish No. 27, from site C, was found 0.3 km (0.15 n mi) east of site A and then moved 0.4 km (0.24 n mi) to the north during a two hour period on the evening of August 29.

On another cruise, one month after releases, we returned to the capture location to study long-term movements. No transmitters were detected in the immediate vicinity of the capture location. After an expanding rectangular search pattern, eight of the 12 transmitters were discovered, all south and a distance of about 0.2 to 1.3 km (0.1 to 0.7 n mi) from the catch location. Locations of these fish were determined for the next 2.5 d during three periods. The fish were scattered along a 2.0 km (1.1 n mi) east-west axis (Fig. V-6). Most fish demonstrated movements of over 0.2 km or 0.1 n mi (our nominal error of navigation) during this cruise. Some (No. 23 and 28) moved about 0.9 km (0.5 n mi). Only one fish (No. 22) for which multiple fixes were obtained ended up near the location where it was originally found on this cruise. There was no evidence that these fish stayed in a common school or within a small home range, as found earlier in the summer.

Vertical Movements: Pressure telemetering transmitters were used during 1989 and 1990, but due to problems with the receiver only limited data were obtained. Figures V-7A and B show the maximum and minimum depths recorded for every 10 min for fish monitored during August 21-22 and 24-25, 1989. Fish were usually in midwater, inhabiting depths of 25 to 50 m (82 to 164 ft) where

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Figure V-7. Depths of yellowtail rockfish No. 2, 3, and 5 with
pressure telemetering transmitters during August 21-24 (Fig.
V-7A) and during August 25, 1989 (Fig. V-7B). Bottom depths
ranged from 75 to 99 m (246 to 325 ft) during this period.
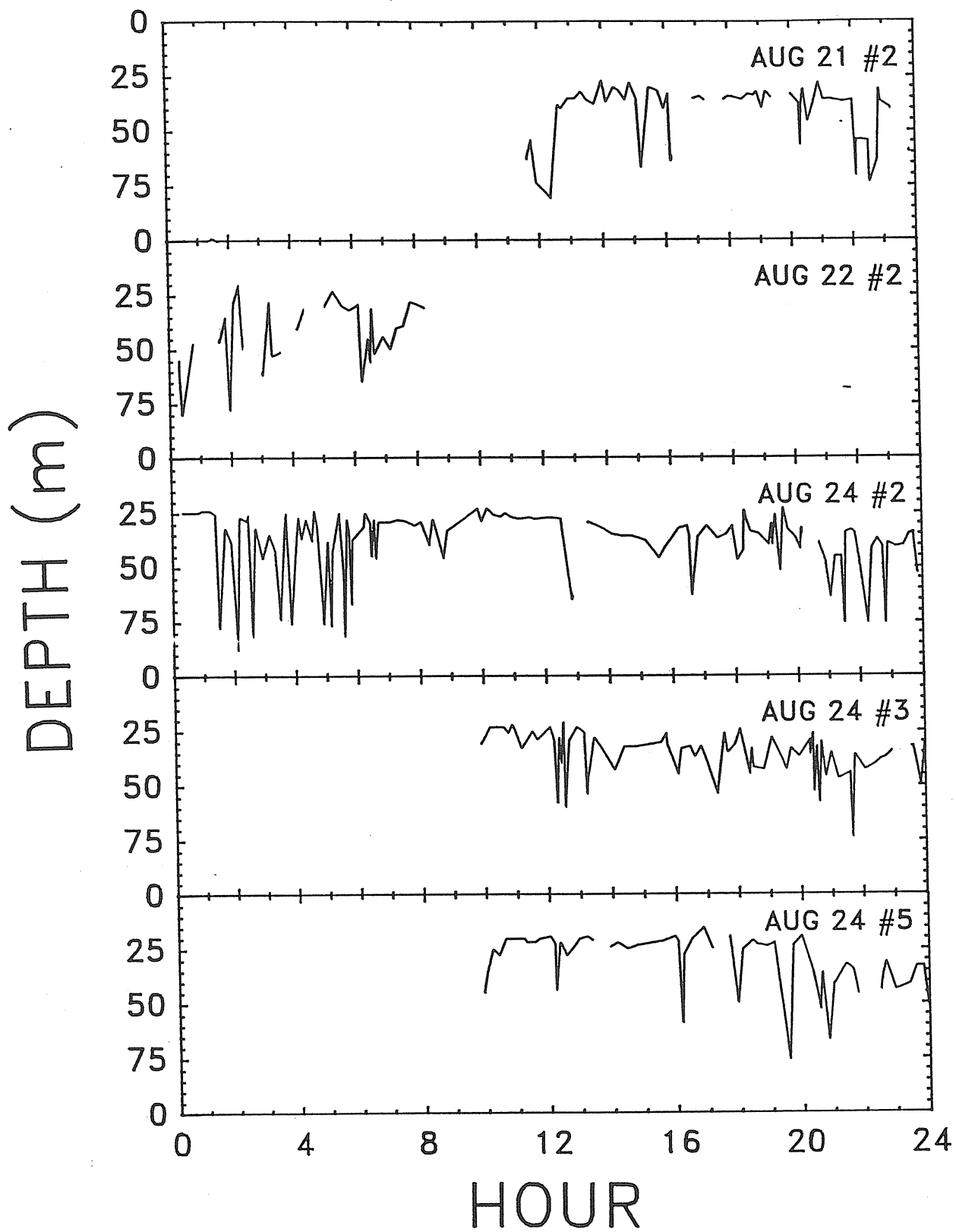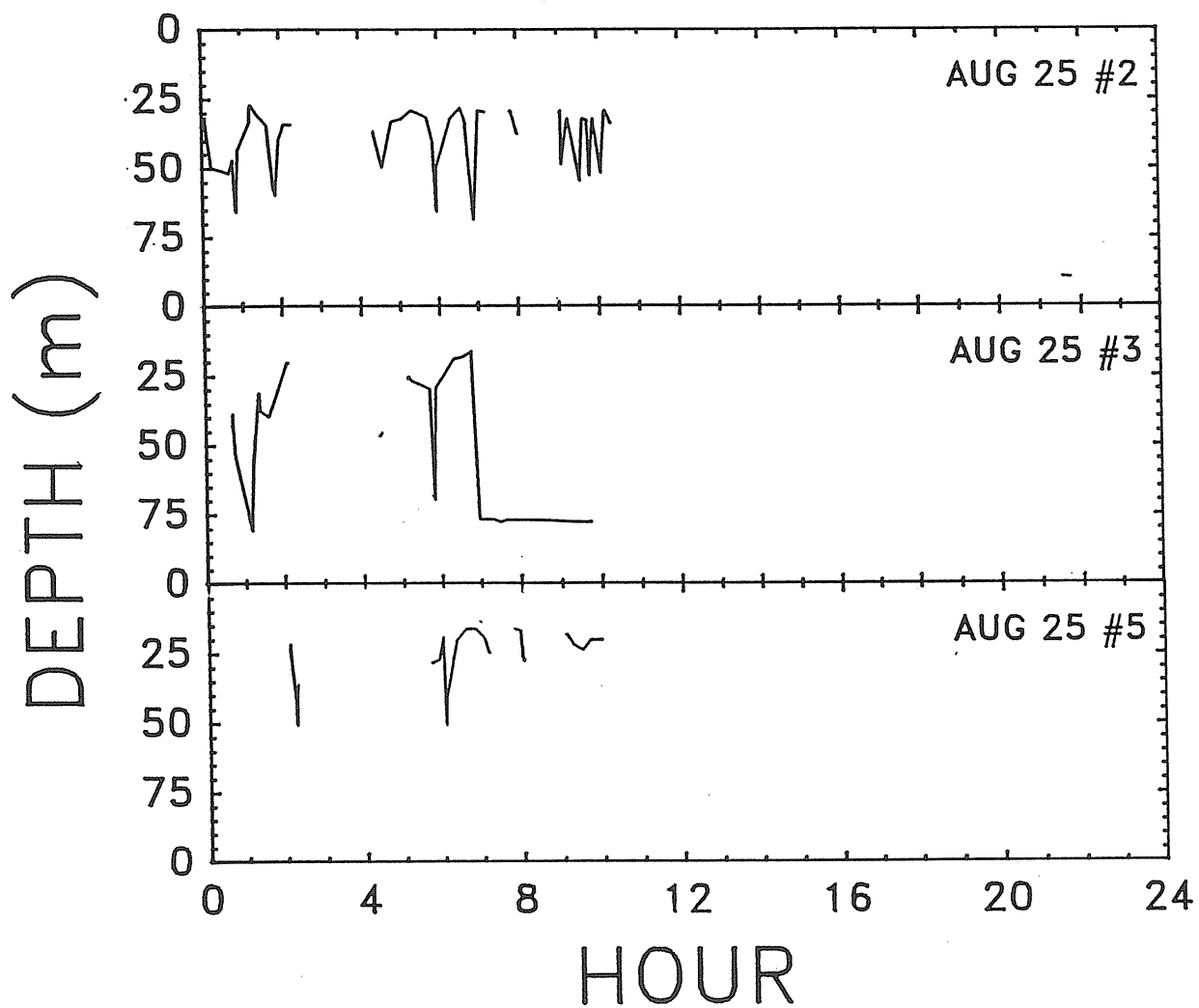
the bottom was about 75 m (246 ft). Short-duration vertical movements were seen for all fish, usually "bounce" dives to or close to the bottom, followed by rapid vertical ascents back to depths of 25-35 m (82-115 ft). Fish No. 2 made nine of these "bounce dives" to the bottom during the early morning of August 24. Other than this series of dives, there was little evidence for any diel patterns in the frequency of vertical migrations of fish that were tagged. Fish No. 3 either regurgitated its transmitter or rested on the bottom after 0700 hrs on August 25 (Fig. V-7B).

Vertical excursions of fish during August 1990 showed a similar pattern, with fish occupying midwater depths and occasionally diving to deep water (Fig. V-8). The records for Fish No. 2 and 3 show that these fish dove toward the bottom immediately after tagging and then rose to progressively shallower depths during the next several hours. Synchronous vertical movements of different fish were not observed in either year.

Maximum rates of descent and ascent of fish tagged in 1990 are shown in Table V-3 for those vertical movements indicated in Fig. V-8. Maximum rates of descent were 0.16 to 0.40 m (0.5 to 1.3 ft) per sec; maximum ascents were 0.15 to 0.31 m (0.5 to 1.0 ft) per sec. Figure V-9 shows the dive of fish 5 after release, with the most rapid descent during the first minute, and slower rates in the next three minutes. Rapid vertical movements were also observed during 1989, with maximum rates of descent of 0.15-0.45 m (0.5 to 1.5 ft) per sec, and rates of ascent of 0.15 m (0.5 ft) per sec.

Figure V-8. Depths of yellowtail rockfish No. 2, 3, 5, and 6

with pressure telemetering transmitters during August 14,

1990. D designates the dives or ascents listed in Table V-3.

Bottom depths were 75-80 m (246-262 ft).
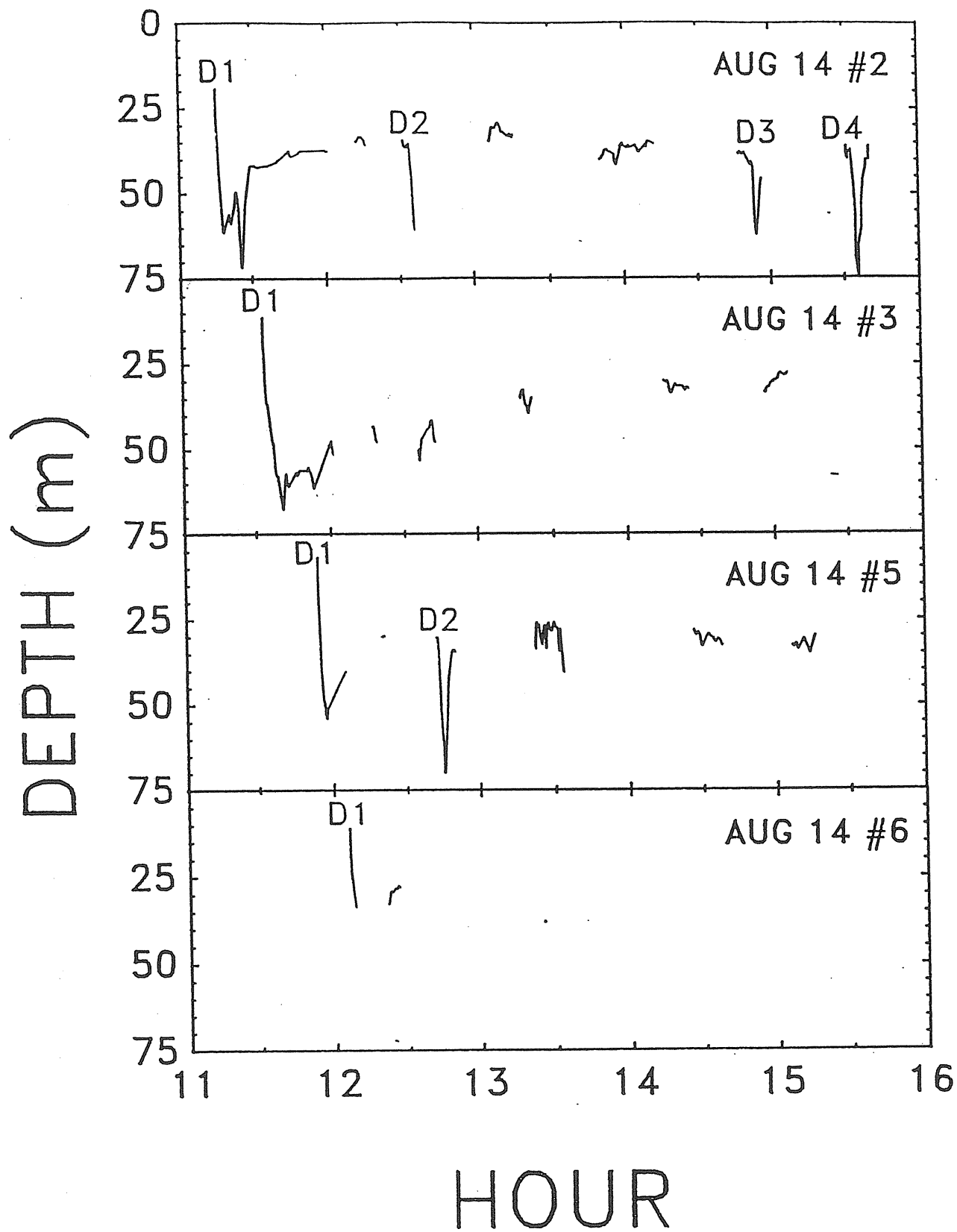
Table V-3. Maximum rates of ascent (A) or descent (D) of
    yellowtail rockfish with pressure telemetering transmitters,
    based on median depths recorded every 25 sec, August 1990 (see
    Fig. 8).

FISH	DIVE	DEPTH CHANGE	RATE OF CHANGE (m/sec)
2	1	19.5-26.9	0.29
	1	51.8-71.8	0.24
	1	71.8-52.5	0.19
	2	36.4-61.0	0.20
	3	42.8-62.4	0.26
	3	62.4-47.6	0.15
	4	37.2-74.8	0.25
3	1	11.4-36.9	0.20
	1	67.9-56.9	0.15
5	1	7.0-39.9	0.40
	2	30.5-70.2	0.26
	2	67.7-44.7	0.31
6	1	11.0-33.7	0.16

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Figure V-9. Initial portion of Dive 1 by Fish 5 starting at 1154

hours, August 14, 1990, after release at the surface (See Fig.

V-8).
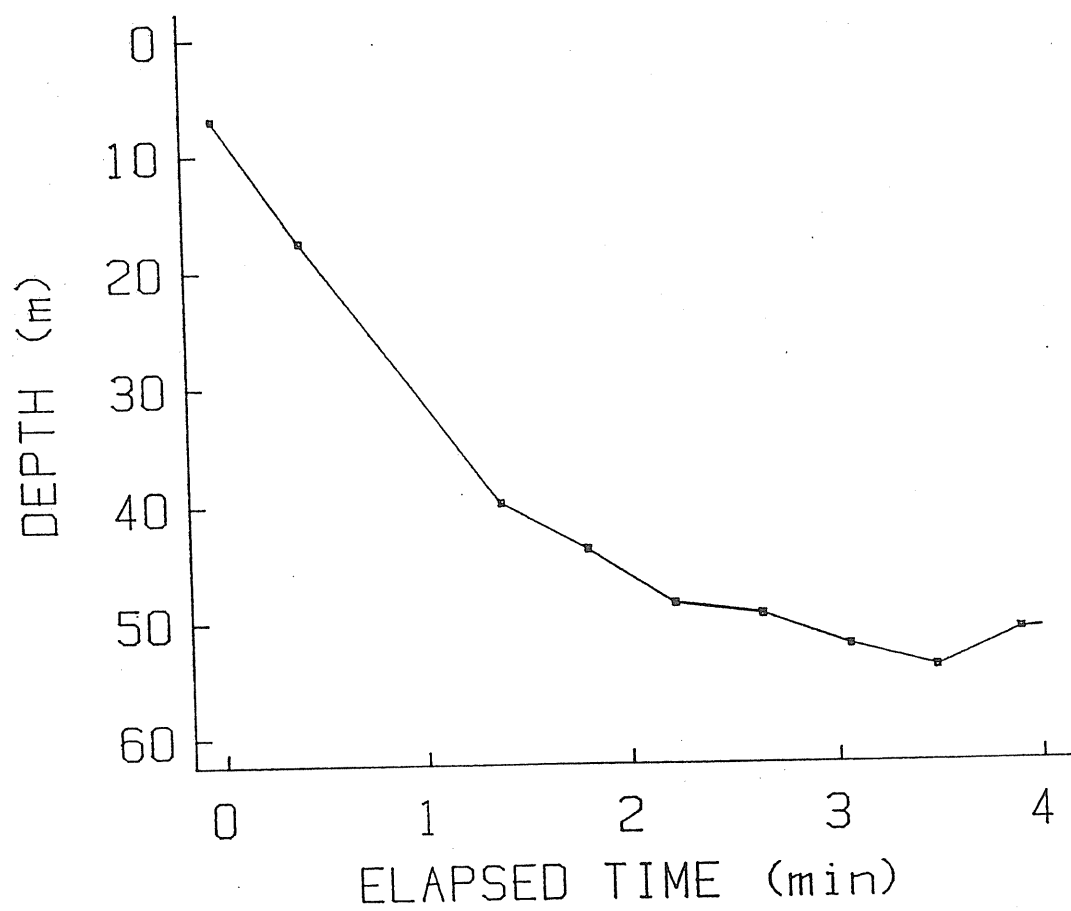
Discussion

<u>Homing and Horizontal Movements</u>: Yellowtail rockfish on Heceta Bank demonstrated strong site fidelity and homing. Fish released up to 4 km (2 n mi) from their capture site over rocky habitat and at similar depths returned to the location of capture. All but one of 12 fish tagged in 1990 returned to or remained close to the capture site 13 days after release. One fish that was displaced 1 km (0.5 n mi) returned overnight to the location where it was captured.

Carlson and Haight (1972) also found that adult yellowtail rockfish returned to their home site, some from as far as 22.5 km (12 n mi), some after displacement to other yellowtail schools, and some after 3 months in captivity. In both their study and mine, yellowtail rockfish homed even if released at sites where the habitat was similar to that at the capture site and near other schools of yellowtail rockfish. This suggests strong fidelity to a home site. Not all yellowtail rockfish demonstrate site tenacity, however. Most of the recoveries of yellowtail rockfish tagged in Puget Sound were from the open Washington coast, indicating an offshore migration probably related to maturation of fish (Mathews and Barker 1983).

Carlson and Haight (1972) found that fish displaced to sites across open water where the depths exceeded 100 m (328 ft) returned to the site of capture much less frequently than fish released along the coast that did not have to swim across deep water to return. The one fish in this study released in deep water off Heceta Bank and tracked for continuously for 14 hours

(Fish 4, Fig. V-3) was not oriented toward its home site. These observations suggest that homing is most effective over shallow water, even though yellowtail rockfish are basically midwater fish. Homing may also be influenced by topography. Matthews et al. (1986) reported that displaced copper and quillback rockfishes (*S. caurinus* and *S. maliger*) returned to high-relief reefs but not to low-relief reefs.

The sensory mechanisms and environmental cues used for homing and home site recognition by yellowtail rockfish are not known. Possibly the fish on Heceta Bank recognized familiar topographic and prominent "landmarks". The yellowtail rockfish that were found dispersed south of their capture location a month after release in 1990 indicate that they do not always have as small a home range and may range over a large portion of the bank. Perhaps they learn visual "landmarks" over much of the bank in this way.

One fish returned to its home site from 0.9 km (0.5 n mi) after only 11 hours, mainly during the night when recognition of visual landmarks would have been more difficult. This fish returned home more rapidly than substrate-associated copper and quillback rockfishes that took 8-25 days to return home after displacement of only 500 m or 1640 ft (see Matthews 1990 for this and summary of homing by other rockfishes).

Eight of the twelve fish tagged in 1990 were relocated one month after release, but they were all south of the capture location and scattered in an east-west direction. This dispersal from the capture site suggests reduced site fidelity and perhaps disassociation of individuals from the large schools

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observed earlier during the summer. This dispersal may be
associated with seasonal changes in the distribution and site
fidelity of yellowtail rockfish, perhaps related to mating
behavior and the fact that most of the fish tagged were large
males. Carlson and Barr (1977) reported that the spatial
distribution and activity of yellowtail and dusky (*S. ciliatus*)
rockfishes differed markedly between May-October, when they were
seen in the water column and apparently actively feeding, and
November-April, when they withdrew into crevices between
boulders. Although no distinct seasonal changes are known in the
bathymetric distribution of yellowtail rockfish (J. Taggart pers.
comm.), the spatial distributions of other species of rockfishes
are known to change seasonally (Patten 1973; Miller and Geibel
1973; Matthews et al. 1986). Several species of juvenile
rockfishes are known to move to deeper reefs with the onset of
fall and winter storms (Love et al. 1991). It would be
interesting to learn if the yellowtail rockfish of Heceta Bank
disperse and become more benthonic during the late fall and
winter, and then if they eventually regroup back at the original
capture location next spring after spawning, or acquire new home
sites on the bank.

Diel Vertical Movements: The yellowtail rockfish of Heceta Bank
were pelagic, swimming far above the bottom most of the time.
Presumably this behavior is typical of yellowtail rockfish that
inhabit deeper and less topographically rugged areas. During
submersible dives, some yellowtail rockfish were observed resting
on the sea floor. More fish were observed inactive on the bottom

during night than day dives. Data from pressure-telemetering tags show that fish dove toward the bottom but remained there only briefly. Only one fish with a pressure transmitter either rested on the bottom for an extended period or disgorged its transmitter.

Little is known about the diel vertical distribution of rockfishes. Schools of *Sebastes entomelas* and *S. proriger* are known to rise off the bottom during the night and become more diffuse than dense schools on the bottom during the day (Leaman et al. 1990). Rockfish may intercept vertically-migrating pelagic organisms that constitute their primary prey, feeding closer to the surface at night or during crepuscular periods and descending with their prey during the day. Sometimes vertically migrating prey, such as euphausiids, are advected onto banks and seamounts and trapped near the bottom during the day where they are devoured by rockfishes (Isaacs and Schwartzlose 1965; Genin et al. 1988; Hobson 1989). Euphausiids are often the primary prey of adult yellowtail rockfish (Lorz et al. 1983). About 50% of the diet by weight of yellowtail rockfish from Heceta Bank was comprised of euphausiids (Brodeur and Pearcy 1984). However, vertically migrating mesopelagic fishes and shrimp were the primary food items of yellowtail rockfish collected in deeper water (137 m or 449 ft bottom depth) along the southern edge of Astoria Canyon (Pereyra et al. 1969).

Yellowtail rockfish from Heceta Bank did not demonstrate obvious diel changes in their behavior by either rising closer to the surface at night or swimming over deeper water to intercept more oceanic organisms. Such behavior has been observed for

other species of rockfishes (Leaman et al. 1990), and predatory shore fishes are known to migrate offshore at night to feed in midwater (Hobson 1968). One yellowtail rockfish on Heceta Bank with a pressure telemetering transmitter made more dives to the bottom during night than day.

The reasons for these dives to the bottom are unclear. One possible explanation is that these dives assist the fish in localizing their position on the bank and preventing drift of the school away from their home station. Surface currents often set the ship away from tagged fish that appeared to be geostationary. Yellowtail rockfish must be able to orient to a specific site and swim against prevailing currents to maintain their position.

Tagging-Tracking Techniques: Sonic tags inserted into the stomachs of yellowtail rockfish without anti-regurgitation mechanisms (ARM's) were useful for tracking fish for several days. Most fish showed detectable movements up to two days after release of fish. Horizontal movements greater than the accuracy of fixes were found in one fish 10 d later but this was an exception. Pressure sensitive tags provided reliable information on the retention of tags since fish were almost always in midwater. Transmitters remained in midwater up to 5 d, the rated duration of the batteries. One pressure-sensitive tag (Fish 3, Fig. V-7B) was apparently regurgitated after 22 h and fell to the bottom. If ARM's were employed, fish movements were measurable for one month after release. One ARM'd tag dropped to the bottom immediately after the fish was released, indicating that restraining hooks are not a guarantee that tags will stay in the

stomach. Eight of the twelve non-pressure telemetering ARM'ed
tags that were relocated moved significant distances 30 d after
the release of fish, indicating long-term retention of
transmitters.

Effects of the transmitter on behavior of the fish are not
known. However, one fish apparently schooled soon after release.
Although fish dove toward the bottom immediately after release,
they rose to typical midwater depths after less than an hour.
These observations suggest that the trauma of being caught,
tagged and released, and the added weight of the transmitter, did
not have prolonged effects.

Conclusions

Site fidelity and homing by yellowtail rockfish is
pronounced. Eleven of 12 acoustically tagged fish were detected
near the location of capture 13 d after release in August 1990,
including three of four fish displaced 0.9 km (0.5 n mi), four of
four fish displaced 3.7 km (2.0 n mi), and all four of the fish
released at the capture site. One fish homed overnight from the
release site 0.9 km (0.5 n mi) away. In September 1990, one
month after release, eight of these fish had abandoned their
prior homesite and dispersed up to 1.3 km (0.7 n mi) to the
south, suggesting a seasonal change in site fidelity.

Yellowtail rockfish usually inhabit midwater depths of 25-35
m (82-115 ft), well above the sea floor at about 75 m (246 ft).
Rapid dives to near-bottom depths are common, but there are no
obvious diel vertical or horizontal migrations.

FOOTNOTE

[1] Bubbles of gas were observed emanating from the region of the opercle as yellowtail rockfish were reeled from about 2-3 m (7-10 ft) depth to the surface. By emersing fish in tanks aboard ship, these bubbles were seen forming and being expelled from under the thin skin between the last gill and the cleithrum anterior to the base of the pectoral fin. Samples of the gas were collected in syringes and analyzed with a microgasometer using the methods of Scholander et al. (1955). The gas was comprised of about 75% oxygen, indicating that gases from the swimbladder were released without causing lethal embolisms when yellowtail rockfish were rapidly decompressed.

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APPENDIX 1

Master list of dominant bottom types, all taxa of fishes,
macroinvertebrates, and other organisms encountered during
submersible transects at Heceta Bank (6 stations, 1988-
1990), Coquille Bank (8 stations, 1990), and Daisy Bank (3
stations, 1990). The grand average percent cover of
dominant bottom types (those accounting for at least 80%
cover of each habitat patch) is given as: ▇ > 80%; ▓ 60-79%;
▓ 40-59%; ░ 20-39%; [blank] < 20%. The grand average
density (number per hectare) of each species is given as: ▇
> 1000; ▓ 100.0-999.9; ▓ 10.0-99.9; ░ 1.0-9.9; and [blank]
0. Presence (X) and absence (blank) of invertebrates at
Coquille and Daisy Banks are also indicated.

	Bank:	Heceta	Coquille	Daisy
Station:		1 2 3 4 5 6	1 2 3 4 5 6 7 8	1 2 3
Year:		889 889 889 889 889 889	9 9 9 9 9 9 9 9	9 9 9
		890 890 890 890 890 890	0 0 0 0 0 0 0 0	0 0 0

DOMINANT BOTTOM TYPE:

Mud
Cobble
Boulder
Rock Ridge
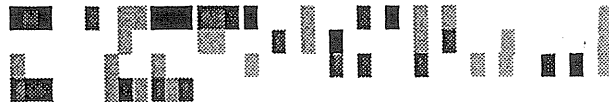
FISH:

Family Myxinidae

Eptatretus sp. (unknown hagfish)

Family Chimaeridae

Hydrolagus colliei (spotted ratfish)

Family Squalidae

Squalus acanthias (spiny dogfish)

Family Rajidae

Raja binoculata (big skate)
Raja kincaidii (sandpaper skate)
Raja rhina (longnose skate)
Raja sp. (unknown skate)

Family Bathylagidae

Bathylagus ochotensis (popeye blacksmelt)

Family Salmonidae

Oncorhynchus sp. (unknown salmon)

Family Myctophidae

unknown lanternfish

Family Merlucciidae

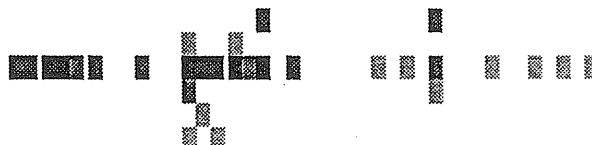*Merluccius productus* (Pacific hake)

Family Ophidiidae

Chilara taylori (spotted cusk-eel)

Family Zoarcidae

Lycodapus mandibularis (pallid eelpout)(?)
Lycodapus sp. (unknown eelpout)
Lycodes cortezianus (bigfin eelpout)
Lycodes diapterus (black eelpout)
Lycodes pacificus (blackbelly eelpout)
unknown slender eelpout

Bank:	Heceta						Coquille								Daisy		
Station:	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3
Year:	889	889	889	889	889	889	9	9	9	9	9	9	9	9	9	9	9
	890	890	890	890	890	890	0	0	0	0	0	0	0	0	0	0	0

Family Scorpaenidae

Sebastes alutus (Pacific Ocean perch)
Sebastes auriculatus (brown rockfish)
Sebastes babcocki (redbanded rockfish)
Sebastes brevispinis (silvergrey rockfish)
Sebastes chlorostictus (greenspotted rockfish)
Sebastes crameri (darkblotched rockfish)
Sebastes diploproa (splitnose rockfish)
Sebastes elongatus (greenstriped rockfish)
Sebastes entomelas (widow rockfish)
Sebastes flavidus (yellowtail rockfish)
Sebastes helvomaculatus (rosethorn rockfish)
Sebastes nigrocinctus (tiger rockfish)
Sebastes paucispinis (bocaccio)
Sebastes pinniger (canary rockfish)
Sebastes proriger (redstripe rockfish)
Sebastes ruberrimus (yelloweye rockfish)
Sebastes wilsoni (pygmy rockfish)
Sebastes zacentrus (sharpchin rockfish)
Sebastes sp. (unknown blotched rockfish)
Sebastes sp. (unknown brown rockfish)
Sebastes sp. (unknown rockfish)
Sebastes sp. (unknown small/juvenile rockfish)
Sebastes sp. (unknown large/adult rockfish)
Sebastolobus alascanus (shortspine thornyhead)
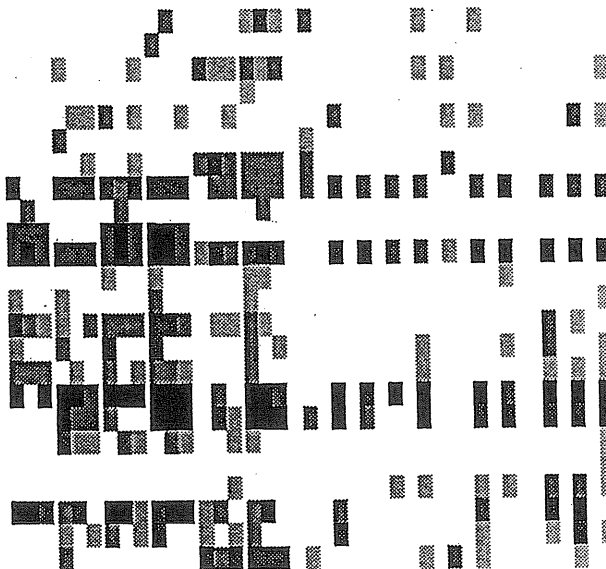
Family Anoplopomatidae

Anoplopoma fimbria (sablefish)

Family Hexagrammidae

Hexagrammos decagrammus (kelp greenling)
Ophiodon elongatus (lingcod)
Oxylebius pictus (painted greenling)

Family Cottidae

Icelinus filamentosus (threadfin sculpin)
Icelinus tenuis (spotfin sculpin)
Icelinus sp. (unknown sculpin)
Paricelius hopliticus (thornback sculpin)
Radulinus asprellus (slim sculpin)
unknown mottled sculpin

Family Agonidae

Agonus acipenserinus (sturgeon poacher)
unknown mottled poacher

Family Liparididae

Careproctus melanurus (blacktail snailfish)

Family Bathymasteridae

Rathbunella sp. (unknown ronquil)

Family Stichaeidae (?)

unknown prickleback (?)

Family Anarhichadidae

Anarrhichthys ocellatus (wolf-eel)

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	Heceta						Coquille								Daisy		
Station:	1	2	3	4	5	6	1	2	3	4	5	6	7	8	1	2	3
Year:	889	889	889	889	889	889	9	9	9	9	9	9	9	9	9	9	9
	890	890	890	890	890	890	0	0	0	0	0	0	0	0	0	0	0

Family Blenniidae (?)

  unknown blenny-like fish (?)

Family Gobiidae

  Coryphopterus nicholsii (blackeye goby)(?)

Family Scombridae

  Scomber japonicus (Pacific mackerel)

Family Bothidae

  Citharichthys sp. (unknown sanddab)

Family Pleuronectidae

  Atheresthes stomias (arrowtooth flounder)
  Eopsetta jordani (petrale sole)
  Glyptocephalus zachirus (rex sole)
  Hipoglossus stenolepis (Pacific halibut)
  Lyopsetta exilis (slender sole)
  Microstomus pacificus (dover sole)
  Parophrys vetulus (English sole)
  Pleuronichthys sp. (unknown turbot)
  Psettichthys melanostictus (sand sole)

NONFISH:

Bacteria

  Beggiotoa spp. (bacterial mat)

Division Chlorophyta (green algae)

  Codium fragile
  Codium sp.

Division Rhodophyta (red algae)

  unknown crustose red alga
  unknown folious red alga

Phylum Porifera (sponges)

  unknown finger sponge
  unknown prickly sponge
  unknown tongue sponge
  unknown tubular sponge
  unknown white fennistrate sponge
  unknown purple globular sponge

   Class Calcarea

  Scypha/Iophon (folious sponge)